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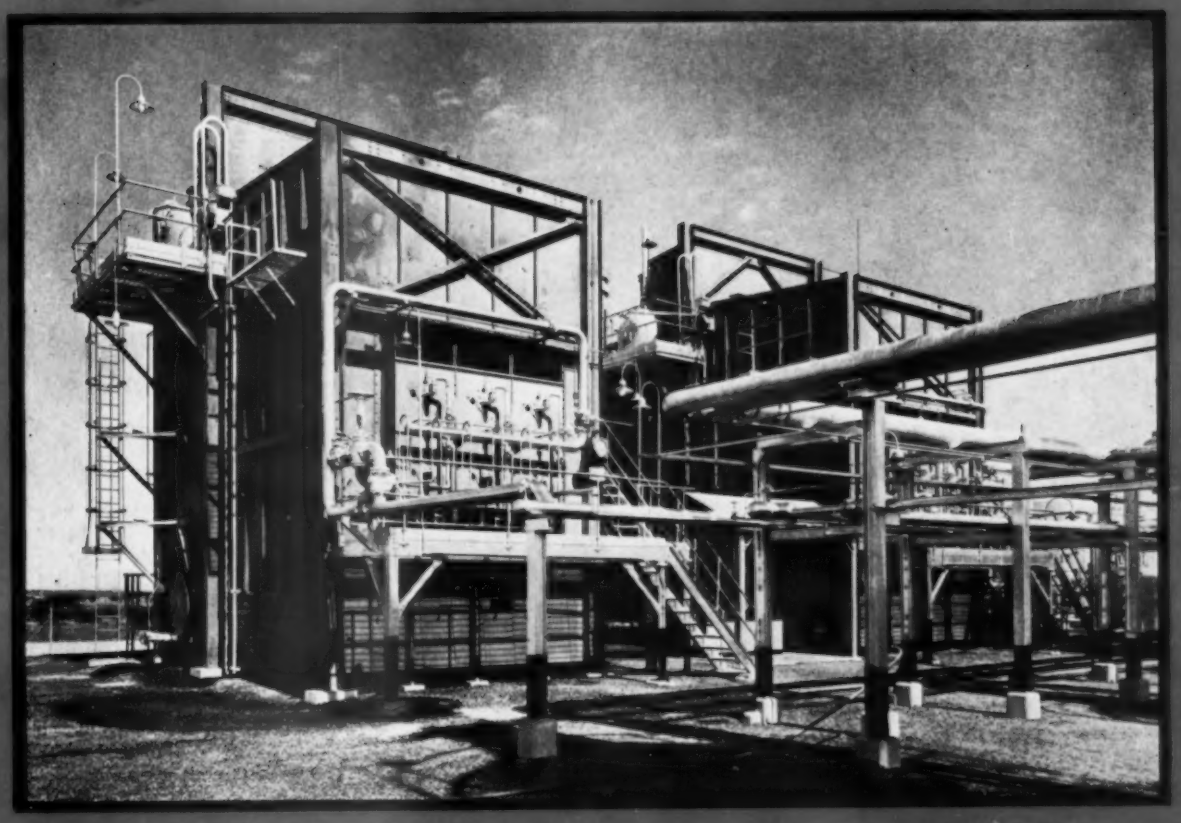

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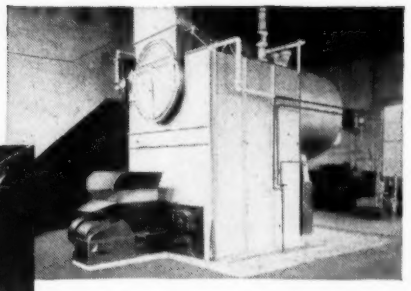
The Reheat Cycle—A Re-evaluation ›

Localized Formation of Magnetic Iron Oxide ›

Labor Saving in Small Boiler Plants ›



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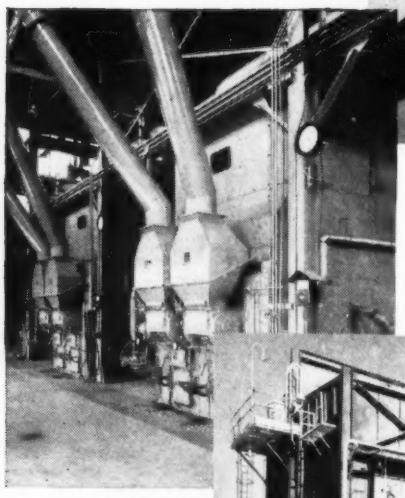

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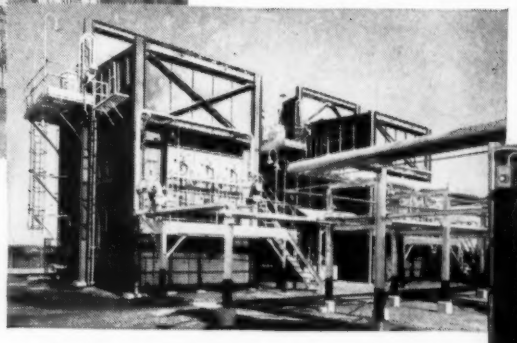

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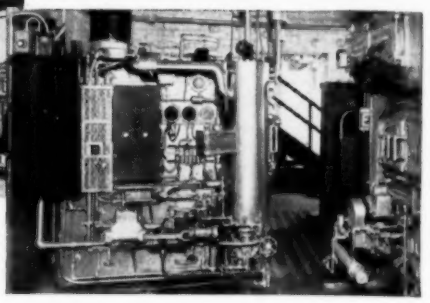

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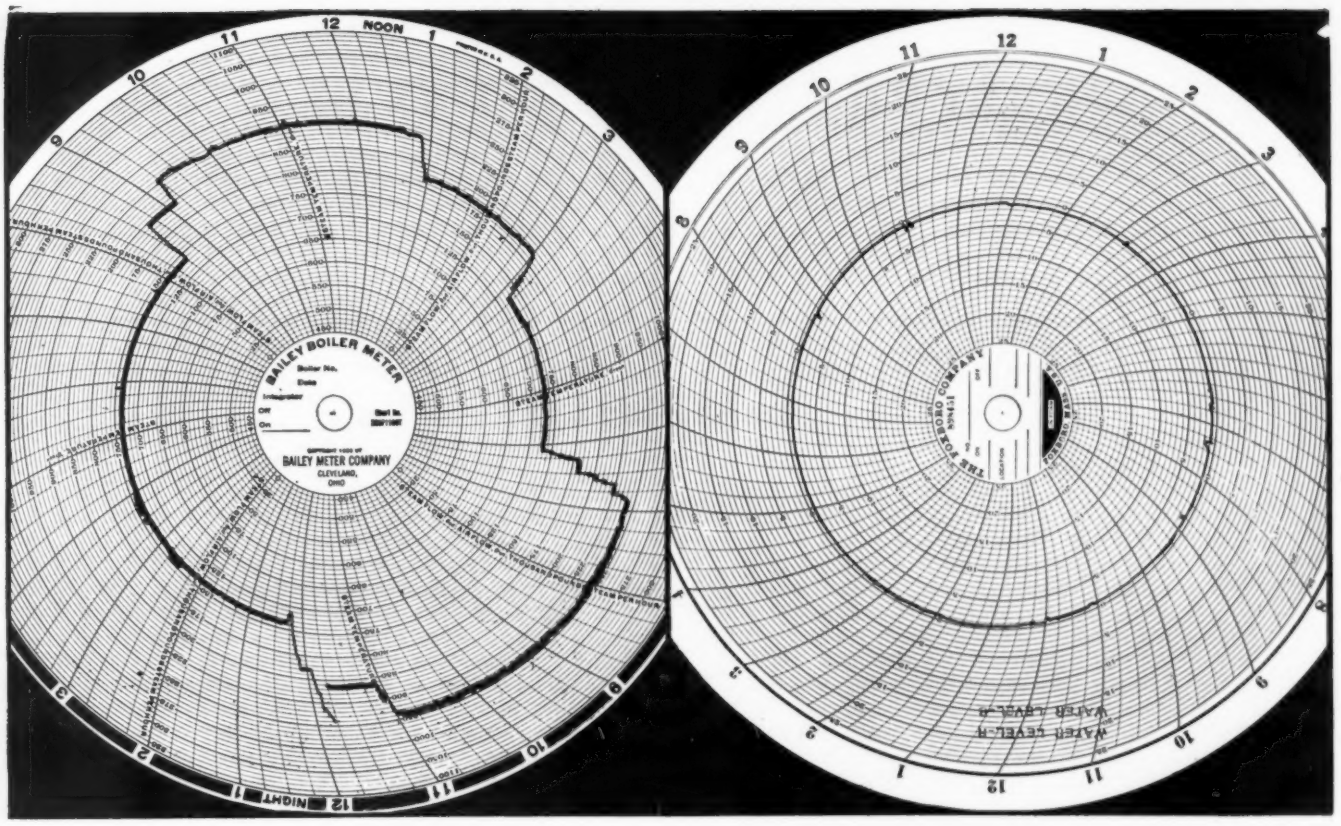

Left: Steam flow from B & W Type FH Boiler rated at 275,000 pounds per hour, 900 psi, 910 F. Right: Drum level held within ±½ inch by COPES Flowmatic

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Editorials

Imported Oil vs. Coal

A subcommittee of the House of Representatives has lately been holding hearings on the influx of foreign oil with reference to its effect on the coal industry, and some of those testifying have advocated a tax levy on imported oil of such magnitude as to curtail greatly the volume coming into this country.

Competition between coal and oil has been cyclic for many years, with oil sometimes in the lead following periodic interruptions in coal supply because of strikes, and the pendulum then swinging back to coal. However, due to a combination of the prolonged curtailment and stoppage of coal supply last fall and winter with the extensive post-war developments in foreign oil fields, there was more than usual conversion to oil. This has resulted in the closing down of numerous high-cost and marginal mines accompanied by some unemployment among miners and on certain coal-carrying railroads.

Despite this, the coal industry as a whole is now reported to be in a healthy condition with attention being focused on a quality product, service and intensive marketing, all of which is expected to lead to a large 1950 tonnage estimated at around 500 million tons.

It is from the standpoint of national security that undue dependence on foreign oil involves a risk, especially that from the Near East; and anything that would tend to weaken the ready availability of coal, which must continue as our basic fuel, should be guarded against. Provision for firing alternate fuels is a security measure that is becoming quite general. Aside from this, the economics of competition are likely to dominate the situation in certain localities.

Commencement Day—1950

Recognition of accomplishment leaves an indelible impresson upon the human mind. Thus it is that recollections of graduation ceremonies—of commencing new phases in life—linger as years move on. Whatever the circumstances may have been, the coming of June brings to mind those days when one left the guidance of trusted teachers and set upon a new course of relative independence.

What of Commencement Day—1950? In large measure due to the G. I. Bill and the "backlog" of persons whose educations were interrupted by World War II, there will be more engineering graduates than in any preceding year. And thanks to the current high level of economic activity, there will be more positions available than seemed possible a few short months ago. However, it is probable that openings in certain phases of engineering-design activity and in some industry-sponsored training programs will not be as numerous as in the past. These factors, in combination with the large numbers of graduates, may have the salutary effect of causing young engineers to seek opportunities in small businesses and in other areas previously left to those whose training was in non-technical fields. Is it not possible that this spreading of the engineering "gospel"—the rationality of accomplishing things for the benefit of mankind by applying the scientific method—may be of inestimable value in the years to come?

Present world conditions demonstrate tragically that science and technical knowledge by themselves are inadequate. Not only are they insufficient for the young engineer embarking upon an uncertain career; their deficiencies have also been made manifest in some of the actions of the leaders and elder statesmen of the world. Even so, there is room for a guarded optimism toward the future, and all of us would do well to ponder seriously these words from a thought-provoking address, "Technical Knowledge Is Not Enough," that James D. Cunningham, president of ASME, has been delivering before sections of that society:

"Our greatest hope for the future lies in the evidence of still another awakening interest in our technical society—an interest in spiritual and moral as well as technical values. Church memberships are growing as people reach out for something they are aware is missing in their lives. Books whose message is a spiritual message are on best-seller lists for the first time in our history and . . . are in greatest demand on our college and university campuses. Here again it is our technical leaders on whom we must depend to give the movement toward spirituality the strength and vigor and endurance that will make it meaningful. Can you turn aside from technical progress to contemplate the greatest and most neglected admonition that has ever been given to man: 'Love thy neighbor as thyself?' If you can, we will find our way out of the difficulties we are in and any others that may come to us. If you cannot, surely we are doomed."

Commencement Day—1950 has real meaning for all who have a working knowledge of human nature, the vision to look beyond immediate obstacles, the ability to plan ahead, and the courage to put their educational resources to practical use for the ultimate benefit of mankind.

THE REHEAT CYCLE— A Re-evaluation

Improved thermal performance and operating economy in the face of rising fuel costs have made the reheat cycle attractive to the electric utility industry. This article, based largely on a study of papers and discussions presented at engineering meetings during the last two years, reviews the advantages and limitations of the reheat cycle; it also takes into consideration some of the intangibles of evaluating the issues of reheat versus non-reheat and cites actual economic studies.

POST-WAR commitments for reheat units in public utility electric generating stations are approaching 50 single boiler-turbine-generator units with a maximum capability approximating 5,000,000 kilowatts. To the question posed nearly three years ago by an article entitled "Is Reheat Coming Back?"[1] these commitments provide an incontrovertible positive answer. Nevertheless, there are those who continue to remain dubious of the technical and economic advantages of the reheat cycle and who claim that reheat cannot be justified for their particular requirements, which may differ but slightly from other systems. It is the purpose of this article to attempt clarification of some of the issues relative to reheat versus non-reheat and to show that the adoption of reheat for appropriate-sized units is not only in accord with the most advanced technical developments, but also where *properly applied* can result in substantial financial returns.

Reheat offers the following advantages:

1. For the same initial steam conditions, reheat makes possible the achievement of a gain in the cycle economy with large turbines, which is estimated at from 4 to 6 per cent,[2] when the steam is reheated to approximately the initial temperature and the reheating is accomplished at the most advantageous pressure. This improvement in cycle efficiency is not to be confused with a still greater improvement in the turbine water rate.

2. The average moisture content of steam during expansion is less; there is an increase in available energy which may be interpreted as a gain in turbine efficiency from the reheat point to the exhaust; the lower moisture content of the steam passing through the lower stages of the turbine tends further to cut down the leaving losses and for the same kilowatt output less steam flow is required.[3]

3. Because of the reduction in steam flow, the condenser, feedwater heaters and related piping may be reduced in size, resulting in capital-investment savings which should be credited to the reheat cycle. These savings tend to compensate for the increased cost of the reheat turbine and boiler.[3]

4. Where cooling-water supply is limited, the reduced heat rejection of the reheat cycle enables the installation of from $7\frac{1}{2}$ to 11 per cent more capacity in reheat than in non-reheat units.[3]

5. Regardless of initial steam conditions as governed by metallurgical advances, the reheat cycle maintains a *theoretical* advantage over the non-reheat regenerative cycle; although a substantial increase over current top steam temperatures would tend to lessen this advantage from the practical standpoint.

6. The inherent greater efficiency of the reheat cycle contributes to the conservation of fuel reserves, a factor which may prove of long-run importance.

7. With the single boiler-turbine-generator unit, complexity of operation, as it existed in the multiple-boiler reheat arrangements of the 1922–1930 era, is no longer a troublesome problem. The reheat boiler is essentially a conventional high-capacity utility-type steam generator with another superheater section interposed, and the operation is no more difficult and requires no more personnel.[4]

Reheat Limitations

Like other technological developments, reheat has limitations and should not be used under circumstances where it cannot be justified by sound engineering analysis. It may be well to review some of the applications for which the reheat cycle has uncertain economic justification. In some cases the factors to be mentioned may well determine the "issue" of reheat versus non-reheat, while in others there may be compensating influences.

The following represent several of the limitations of the reheat cycle:

1. Though the figure cannot be precisely defined, fuel costs may be so low that reheat cannot be justified solely on the higher operating efficiency of the reheat cycle.

2. Utility systems may be so limited in size that units having a nameplate rating of 40,000 kw—the smallest turbine-generator units now commercially available for reheat—may not be justifiable.

3. Where utility-system capacity is dominated by hydro power and steam-plant operation is at a compara-

[1] See COMBUSTION, vol. 19, Sept. 1947, pp. 33–34.
[2] "Symposium on the Reheat Cycle," *Trans.* ASME, vol. 71, Aug. 1949, pp. 673–749.
[3] Harris, E. E., and A. O. White, "Developments in Resuperheating in Steam Power Plants," *Trans.* ASME, vol. 71, Aug. 1949, pp. 685–691.
[4] Patterson, W. S., "Modern Reheat Boilers," *Trans.* ASME, vol. 71, Aug. 1949, pp. 729–734.

tively low load factor, justification of the reheat cycle may be difficult.

4. When arrangements involving the pattern of *multiple boilers per turbine* are insisted upon, some of the advantages of the reheat cycle are counteracted by operating problems inherent in the more complex piping systems and centralized controls which are required.

5. There are some who object to the relatively large piping required to handle the reheat steam.

An objective analysis of the issues relative to reheat versus non-reheat necessarily involves certain intangible factors for which no arbitrary rules can be formulated and which must be decided on the merits of individual cases. A partial listing of these intangibles includes the following:

1. Utility system reserve capacity must be evaluated with respect to the possible effects of the addition of generating capacity. Important factors in such evaluations relate to equipment reliability and the strength and dependability of system interconnections.

2. Objections to the reheat cycle on grounds of operating complexity, response to variable loads, and problems of frequent starting and stopping may be more psychological than real when interpreted in terms of physical construction of current simplified-reheat-cycle units and actual operating experience.

3. Use factor over the life of the unit, reheat or non-reheat, is a crucial and controversial point in making an economic evaluation. A "pro-reheat" attitude which is reflected in preferential loading of the most efficient units for their first years of operation gives quite a different result from an "anti-reheat" approach in which allowance is made for presumed complexity of operation and reduced unit availability.

4. In some cases utility system interconnection may help to justify reheat by making most effective use of the units having highest efficiency, and by creating a greater reserve capacity from which to draw during repairs and maintenance outage.

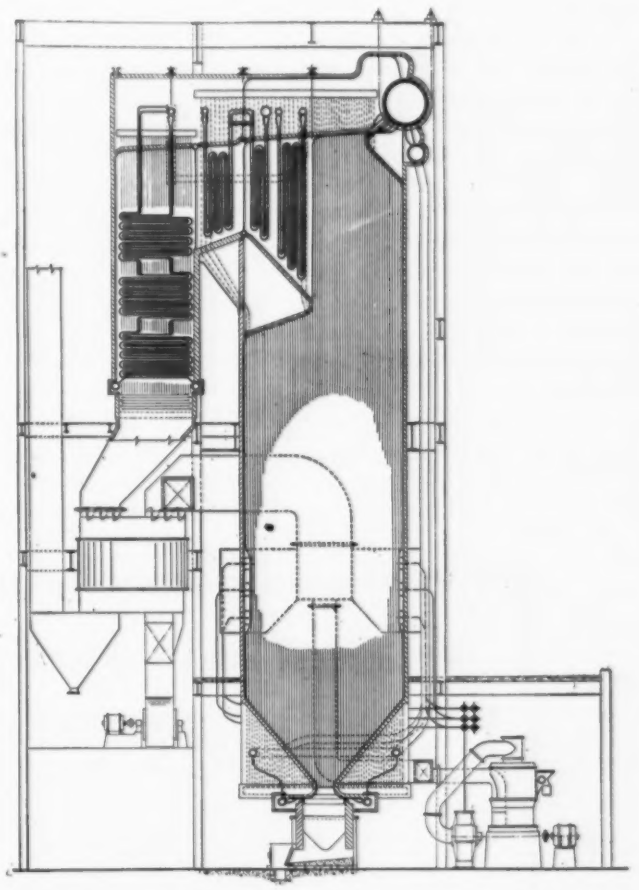
5. The simplified-reheat-cycle station shares many of the advantages of the single-boiler-turbine-generator unit. A recent study[5] provided evidence that investment savings of approximately 4 per cent were made possible by unit design and that these savings more than offset the charges for the smaller reserve requirement of the multiple-boiler, cross-connected header-type station.

6. Despite some debate on the availability of reheat units, the 14-year record of the Port Washington Station[6] of the Wisconsin Electric Power Co. indicates unit-system reliability and dependability which have been surpassed by few, if any, power stations in this country. Actually the factors which affect availability are generally the same for both the reheat and the non-reheat cycles.

Station Heat Rates Compared

An analysis of eight post-war central stations, descriptions of which have appeared over the last year and a half in COMBUSTION, discloses that the average calculated net station heat rate is 11,022 Btu per kwhr. All of the stations under consideration operate on the non-reheat regenerative cycle and represent many of the advances in engineering design incorporated in utility plants built since the end of World War II. Assuming that the substitution of reheat for the non-reheat cycle involves, conservatively, an improvement in thermal efficiency of 4.5 per cent, the reduction in average plant heat rate would be 496 Btu per kwhr, or an average calculated net station heat rate of 10,526 Btu per kwhr.

An economic study[7] presented at the 1949 ASME Annual Meeting analyzed the differences in cost of the various elements of a steam-electric power plant for units



Section through a typical modern high-pressure, high-temperature reheat unit of large capacity

having a capability of 100,000 kw and operating on the reheat or non-reheat cycle. For steam conditions of 1450 psig, 1000/1000 F, the credits for parts of a plant which vary in size either inversely with cycle efficiency or more than indicated by change in efficiency would amount to $2.16 per kw. Debits for parts of a plant which cost more for reheat than for non-reheat, assuming the same unit capability and plants constructed at new locations, are found to equal $3.88 per kw, leaving a net charge for reheat of $1.72.

With coal costing $7.50 per short ton and a coal rate of 0.8 lb per kwhr and 5000 hours per year use, the annual saving for reheat over non-reheat amounts to $0.75 per kw per year. After allowing 10 per cent of the net reheat

[5] Lyman, W. J., C. E. Mullan and R. M. Buchanan, "Economic Evaluation of Unit-Type Generating Stations," reported in COMBUSTION, vol. 21, May 1950, pp. 55–56.

[6] "1949 Port Washington Experiences," COMBUSTION, vol. 21, January 1950, pp. 45–48.

[7] Moore, R. P., "A Comparison of Costs of Reheat Versus Non-Reheat for 100 Mw Units," ASME paper no. 49-A-99, reported in COMBUSTION, vol. 21, December 1949, pp. 40–41.

charge for interest, insurance and taxes, there remains a savings of $0.58 per kw per year. In itself this is sufficient to write off the net charge for reheat in approximately three years.

Conclusions

Many other similar studies could be cited to provide evidence of the economic advantages of the reheat cycle when applied under conditions that are favorable to its use. However, it seems well to conclude with the following quotation, by a well-known mechanical engineer, from the discussion of the 1948 ASME "Symposium on the Reheat Cycle":[8]

"Then why wasn't the reheat cycle popular prior to the present sizable crop? Largely because confidence in the availability of large boilers was not general, especially when poorer grades of coal were used. The reheat cycle demands a single boiler-turbine combination; this means single boilers with a capacity of 80,000 to 150,000 kw. Until a few years ago, boilers were forced to the point where availability was affected. Present day boilers are, on the whole, more liberally designed; this means much improved availability and confidence in large single boilers. . . These would have been many more reheat plants today had these papers been presented a few years ago."

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[8] Krieg, Edwin H., "Symposium on the Reheat Cycle—Discussion," *Trans.* ASME, vol. 71, Aug. 1949, p. 740.

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Localized Formation of Magnetic Iron Oxide in Power Boilers*

By H. M. RIVERS and W. M. SONNETT
Hall Laboratories, Inc.
Pittsburgh, Pa.

A thin film of magnetic iron oxide normally protects boiler metal from spontaneous attack by water. Corrosion occurs if, and only if, the protective film is destroyed. Erosion, sudden temperature changes and other physical or mechanical factors may damage the protective film and permit corrosion. Chemical breakdown of the film may be caused by oxygen, galvanic forces set up by porous or lightly adherent deposits, strong concentration of boiler water caustic or exposure to superheated steam at very high temperature. Any condition that aids these corrosive influences—localized overheating, retarded circulation, steam blanketing, etc. —contributes to the attack. Magnetic iron oxide, produced in proportion to the loss of metal, may remain near the corroded area or deposit elsewhere in the boiler. The hydrogen inevitably released by reaction between water and steel either passes off with the steam or is absorbed by the metal, sometimes causing brittleness and weakness due to intergranular damage. Metal which has failed through overheating, as indicated by changes in microstructure, always shows signs of corrosion, unless a layer of scale has sealed the metal away from direct contact with water or steam.

IRON in contact with boiler water tends to corrode spontaneously. Water is decomposed in the process, liberating hydrogen gas and producing magnetic iron oxide (Fe_3O_4) as the main corrosion product. Being extremely insoluble, this iron oxide normally precipitates directly on the metal, forming a tightly adherent barrier of film thickness which practically stops the corrosion process. Any further action is negligible unless something destroys the protective oxide film. Thus, the iron oxide usually found on boiler surfaces exists as a perfectly natural, highly desirable protective film over the metal.

Strictly speaking, the causes of corrosion are simply those factors—mechanical, chemical or otherwise—which expose bare metal to direct contact with water. Prevention of corrosion in boilers is mainly a problem of keeping the natural oxide coating intact; any occurrence of corrosion necessarily implies that the protective film has broken down.

Boiler steel may corrode in a variety of forms. Characteristic changes in the physical appearance or the microstructure of the metal may aid in identifying the various corrosion forms; but these are not always sharply distinguishable from one another, and often two or more forms appear together. The case histories presented here illustrate rather clear-cut examples of several types of attack: simple corrosion by high concentration of caustic, corrosion by caustic in the concentrating film, attack under adherent deposits, hydrogen damage, gouging caused by steam blanketing and corrosion fatigue. All have been carefully selected to develop a coherent picture of the corrosion mechanisms responsible for localized formation of magnetic iron oxide in power boilers.

Corrosion in the Form of Pitting

Oxygen dissolved in boiler water causes corrosion in the form of pits characteristically filled or covered with iron oxide. Such pits are not ordinarily restricted to heat-transfer surfaces. Good deaeration and oxygen-scavenging chemicals generally suffice to control this type of attack. But steel sometimes continues to corrode under old tubercles of oxide when no measurable amount of dissolved oxygen is present, even defying strong residuals of scavenging chemical in the boiler water. To account for this activity on non-heat-transfer surfaces in the absence of oxygen, it is supposed that the corrosion products form a water-permeable membrane, setting up differences in concentration which allow the metal underneath to become relatively anodic and thereby corrode, while water is decomposed to supply oxygen for production of more iron oxide. Patches of mill scale or spots of rust developed during stand-by may perhaps incite corrosion of this type. Once started, the process accelerates under a thickening layer of oxide and tends to continue until failure occurs or until the oxide deposit is removed. Interesting examples of this type of corrosion are cited by Corey (1) and by Hankison and Baker (2), the latter illustrating attack focused on rust spots formed after acid washing of the boiler. Chemical

* A paper presented at the 1950 Midwest Power Conference.

cleaning and sandblasting, where practical, offer modes of attack on this problem; the pits are opened up, permitting a new film of protective oxide to form, but care must be taken to minimize after-rusting, lest the process start all over again.

Pitted or pock-marked metal often appears beneath accumulations of iron oxide, suggesting a galvanic or "concentration cell" effect similar to that just described. The oxide deposit may be dense and adherent, presumably due to corrosion on the spot; or it may be fairly soft and loose, indicating that some or most of it originated elsewhere—either at other parts of the boiler, or as an

Fig. 1—Water-line corrosion due to high caustic concentration on a desuperheater inlet connection

impurity in the boiler feedwater. Since iron oxides and dissolved iron have a natural tendency to form magnetic iron oxide in the boiler water, it is difficult to trace the origin of all the oxide which may be found at a particular place. Also, the iron oxide may be mixed with various amounts of copper, cuprous oxide and ordinary light boiler water sludge. In general, pitting is likely to be found under deposits in which iron oxide predominates greatly over the normal sludge material.

Copper is a common, although certainly not inevitable, companion of iron oxide in deposits associated with corrosion. If copper actually aids corrosion under certain conditions, the mechanism is not clearly known. Cuprous oxide or very minute amounts of dissolved copper might find their way to regions where corrosion is either imminent or has already commenced. It is suggested that these materials may depolarize cathodic areas, by removing the polarizing hydrogen, and thus encourage any corrosive tendencies which might prevail. Some such mechanism could account for the presence of metallic copper in many corrosion deposits. At most, copper may contribute to the corrosion process but is not essential to it; corrosion cases of all types are known in which no evidence of copper could be found. Of course, anything that adds bulk or density to a deposit—iron oxide, copper or inert sludge—may magnify the differences in concentration which give rise to this galvanic type of attack.

Attack on a Heat-Transfer Surface by Caustic in the Concentrating Film

It is well known that acid solutions may dissolve the protective oxide coating over steel and thereby promote corrosion. Highly alkaline solutions behave in the same way. In this case, chemical reaction between iron oxide and alkali (e.g., sodium hydroxide) evidently produces soluble sodium-iron salts, such as Na_2FeO_2 and $Na_2Fe_2O_4$. These reactions are analogous to those formed by dissolution of aluminum, tin and zinc in alkaline water, although, in general, much higher concentrations and temperature of alkali are required to produce this effect on iron. If a solution containing dissolved sodium-iron salts is diluted with water, black magnetic iron oxide (Fe_3O_4) precipitates. Corrosion of boiler steel, when caused by a high concentration of caustic developed in the concentrating film on a heat-transfer surface, may leave iron oxide deposits near or removed from the point of attack, depending upon circulation characteristics in the region where final dilution occurs.

An instance of desuperheater failure in a marine boiler illustrates the mechanism of attack by caustic in the concentrating film. Superheated steam at 450 psi and 750 F was passed through a desuperheater submerged in the upper drum. The inlet connection to the desuperheater entered the water at an angle of about 45 deg. Fig. 1 depicts the severe attack which occurred just above

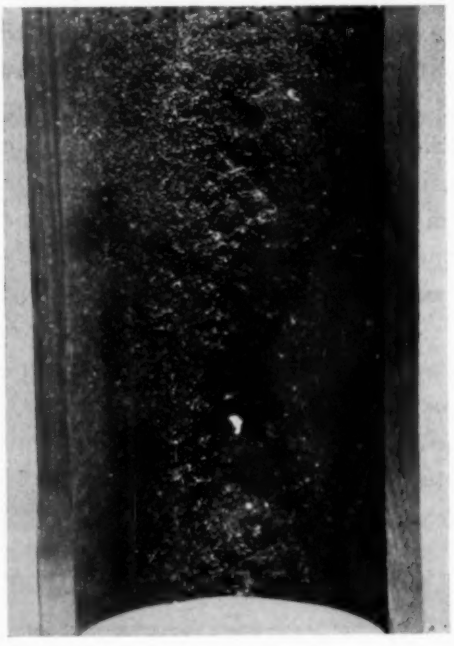

Fig. 2—Localized attack on a heat-transfer surface by caustic in the concentrating film

water level. Feedwater, discharging into the drum some distance away from the failure, showed less than 0.05 ppm dissolved oxygen. Absence of oxygen corrosion anywhere in the boiler further discounted the possibility that this was a case of oxygen attack. All evidence pointed to caustic corrosion as the cause of the damage. Boiler water, containing a normal amount of free caustic alkalinity, splashed onto the hot tube above water level and evaporated there. Being inadequately rinsed by fresh boiler water, this surface accumulated a

concentration of caustic sufficient to dissolve the protective oxide film; this exposed bare metal to further reaction with water, and produced more oxide at the expense of sound metal. Continual repetition of this procees caused thinning of the tube and eventual failure in a localized region just above water level. As might be expected, no sign of corrosion appeared below water level where metal was not exposed to the action of strong alkali. Submerging the inlet connection would represent a logical remedy for the difficulty in this particular instance.

The failure shown in Fig. 2 resulted from causes similar to those just described, but under totally different circumstances. This happened to one of the roof tubes in a 1350-psi boiler. Failure was in the form of a puncture, there being no evidence of change in the microstructure of the metal, nor any noticeable distortion of the tube. Most of the visible surface is marred by tiny pinholes where attack has just commenced. Spongy material surrounding the major pit is mainly magnetic iron oxide, some of it well crystallized and displaying a metallic luster. A space of bare metal immediately surrounds the point of failure. Attack may have been most severe in the depth of the pit where caustic concentration presumably was highest, with the corrosion products being washed completely away in the form of soluble sodium-iron salts or suspended iron oxide sludge; or high velocity of water escaping through the puncture may have scoured off any deposit present. At the edge of the pit, and for some distance beyond it, alkali concentration was evidently low enough to precipitate iron oxide in tightly adherent form. In this and many similar instances, elimination of alkali attack requires virtually complete exclusion of alkalinity from the boiler water.

The examples cited by Figs. 1 and 2 bring out clearly the three essential features of corrosive attack by caustic in the concentrating film: (1) the boiler water must contain free caustic (hydroxide) alkalinity; (2) evaporation must occur on surfaces whose temperature exceeds that of saturated steam; and (3) rinsing of these surfaces by fresh boiler water must be insufficient to wash away the concentrated caustic solution produced by evaporation.

Caustic Attack Under Adherent Deposits

It is not uncommon to find evidence of caustic corrosion under a porous deposit of adherent sludge or scale. Boiler water seeps down through the deposit, evaporates and leaves behind its burden of dissolved and suspended solids. Some of these solids precipitate as scale or sludge material within the original deposit. Caustic soda, being extremely soluble, does not crystallize out of solution but tends to concentrate at the metal surface. Eventually, concentration of caustic becomes great enough to dissolve the protective oxide coating over the metal, and corrosion results. Soluble sodium-iron salts thus formed work their way back through the deposit to regions of lower caustic concentration and ultimately precipitate as magnetic iron oxide. This oxide encourages further corrosion by preventing the underlying concentrated caustic solution from mixing with normal boiler water. The process, accordingly, tends to accelerate itself.

A typical case of corrosion attributable to high concentration of caustic under a deposit of iron oxide is presented in Fig. 3. This tube from a 250-psi boiler had almost completely wasted away around its entire circumference near the section shown. While all of the inner surface is coated with oxide, deposition at the bottom of the tube is quite thick and is definitely laminated in structure. Tiny flecks of white throughout the deposit represent sparkling crystals of magnetite (Fe_3O_4) which appear in great abundance. The material is principally magnetic iron oxide, but it contains some quartz and an appreciable amount of water-soluble sodium salts. Great though the loss of metal was, this and adjacent sections of the tube contained more oxide than could be accounted for by corrosion in the immediate vicinity. Much of this oxide must have come from the badly gouged surfaces shortly

Fig. 3—Attack by highly concentrated boiler water under a deposit of magnetic iron oxide

upstream from the point of failure. This gouging, incidentally, was along the upper part of the tube while surfaces diametrically opposite showed no signs of corrosion or deposition of any kind. This failure took place at the bottom of the tube under an inordinately thick layer of iron oxide. Corrosion evident in this illustration occurred under a deposit which was firm but porous enough to admit boiler water and allow its caustic to concentrate aggressively.

Hall and Kaufman (3), and later Straub (4), have recorded similar cases of corrosion due to high concentration of caustic under deposits of magnetic iron oxide. This type of attack is possible when any mechanical barrier permits boiler water to reach metal of elevated temperature but interferes with rinsing processes which normally would dissipate the concentrating film containing caustic. Relief from this kind of corrosion clearly requires, as it did in the example of Fig. 3, considerably more circulation of boiler water through the affected tubes, and, possibly, some reduction in heat input. It should be remembered that the offending solid in such cases is not boiler scale but corrosion product. This oxide should be removed from tubes not damaged enough to require replacement by mechanical or chemical cleaning.

The sodium-iron salts produced by caustic attack remain dissolved only in highly alkaline solution. When such a solution is mixed with comparatively dilute boiler water, magnetic iron oxide precipitates spontaneously. If water flow is vigorous or turbulent where precipitation

takes place, the resulting oxide may be carried some distance away from the point of corrosion. This accounts for the loose accumulations of black oxide often found in headers, drums and tubes of boilers experiencing caustic attack. Loose chips of black oxide, on the other hand, may indicate that concentrated caustic has dissolved the bond between the metal and the oxide deposit, causing the latter to slough off in pieces. Sudden changes in temperature (e.g., those caused by periodic quenching of overheated surfaces) may also dislodge pieces of otherwise adherent iron oxide. Boiler surfaces are sometimes covered with light-colored boiler water sludge or soft scale presenting a mottled or blistered appearance. Semi-detached deposit will be black on the metal side, and metal underneath will be bright or covered with glittering crystals of black iron oxide, showing the effects of caustic which has concentrated between the deposit and the metal.

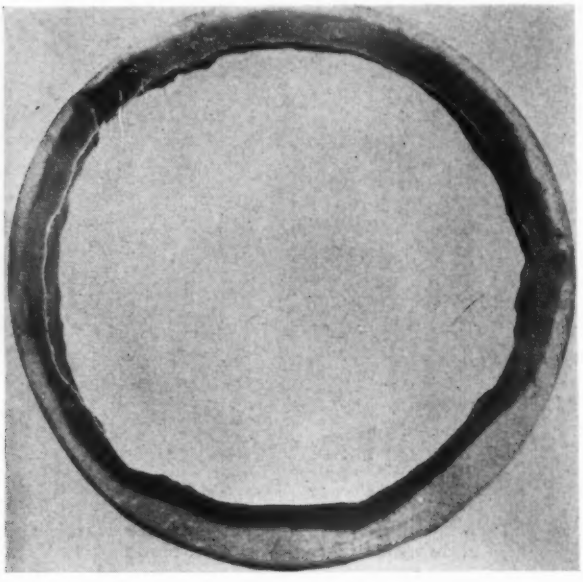

Fig. 4—Hydrogen damage associated with caustic corrosion

Special mention should be made of the iron oxide found in boilers as a result of iron contamination from outside sources, as well as that produced by acid washing or liberated for a short time after a new boiler goes in operation. Such oxide may well contribute to the corrosion mechanisms being discussed, for instance by abetting or creating a concentrating film condition. Regardless of its origin, iron oxide predominantly assumes the black magnetic form (Fe_3O_4) under boiler water conditions. This is especially true of the oxide associated with most boiler failures.

Hydrogen Damage

Hydrogen is necessarily formed during any corrosion process in which water reacts with steel. Tests for gaseous hydrogen in steam are sometimes made to determine the rate of corrosion in a boiler. Such indications are not trustworthy because most or all of the hydrogen may be absorbed by the steel at the point of damage. Also, a given amount of hydrogen in the steam might represent comparatively insignificant generalized attack, or extremely severe corrosion in localized areas. Considering that hydrogen admitted with the feedwater may be totally absorbed by the boiler metal, tests for hydrogen in steam or water provide hardly more than a qualitative indication of any corrosion which may be in progress.

Some hydrogen will dissolve in iron even at ordinary temperature, producing slight but temporary brittleness which disappears if the metal is heated sufficiently to expel the dissolved hydrogen. At higher temperatures, hydrogen may cause serious permanent damage by changing the microstructure of the metal. Chemical reaction between hydrogen and combined carbon in the steel produces methane (CH_4). Because the larger molecules of methane cannot diffuse through the steel as readily as the small atoms of hydrogen, the methane collects at the grain boundaries, exerting a force which tends to pry the grains apart. Under stress, steel that has suffered from hydrogen damage is inclined to crack along the weakened intercrystalline paths. Thick-edge fractures are characteristic of tube failures resulting from this cause. Production of hydrogen damage generally requires relatively high metal temperature, although not necessarily high enough to cause structural changes characteristic of overheating.

An example of caustic attack, associated with hydrogen damage, is illustrated in Fig. 4. Pictured here is part of a 4-in. slag screen tube which failed in a 1250-psi boiler. The tube wall is noticeably thinned around its whole inner circumference, being corroded about half way through at the top. Originally, the inside surface was coated by an adherent layer of highly magnetic material, mainly black oxide with minor amounts of copper and silica, the deposit being thickest near regions of greatest wall thinning. All of this material came off when the specimen was etched with acid to check for evidence of hydrogen damage. Before etching, the polished cross-section was uniformly bright and presented a normal metallic appearance. Etching brought out the darkened area, indicative of hydrogen damage around the entire tube and extending almost through the metal in places. The thick-edge longitudinal crack at the point of failure is characteristic. Metallographic examination disclosed severe intergranular attack typical of hydrogen damage, but the tube had not been overheated sufficiently to change the microstructure in the outer shell of sound steel. The hydrogen damage and loss of metal are symptomatic of a corrosion process. Highly concentrated boiler water caustic has destroyed the metal's protective oxide covering, and iron has reacted with water to produce iron oxide. The other corrosion product, hydrogen, has entered the metal to cause a characteristic form of intergranular damage.

Specific Effects of Temperature

Laboratory tests by Berl and van Taack (5, 6) indicated that caustic solutions stronger than 5 per cent would attack the oxide film on boiler steel at 590 F. Kaufman, Marcy and Trautman (7) found that 5 per cent caustic solution at 470 F could, in 22 hr, remove the iron oxide previously formed on the wall of a steel bomb. These data, in agreement with estimates based on actual case histories, suggest that attack on steel may occur when boiler water caustic is concentrated to no more than a 5 per cent solution. The boiling temperature of 5 per cent caustic solution is a little over 2 deg F above that of water boiling at the same pressure. It is a well known

fact (q.v., Duhring's rule) that the boiling point elevation due to a given quantity of caustic in solution is substantially the same over an extremely wide range of pressures. What it means is this: if the temperature of a tube surface wetted by boiler water is only a few degrees higher than that of the main body of boiler water, for a given pressure, then the concentrating film may develop a content of caustic which is high enough to attack the protective oxide film and allow corrosion to occur.

Even with conservative heat transfer rates, normal circulation of water through generating tubes and no deposits on steaming surfaces, it is quite possible to get temperature drops of several degrees from metal to boiling liquid. For example, assuming (8) a heat-transfer film coefficient of 5000 Btu/hr/sq ft/deg F, heat input at the rate of only 15,000 Btu/hr/sq ft would raise the inside metal temperature 3 deg above that of saturated steam, which is quite enough to establish a critical concentration of caustic at the metal-water interface. Caustic corrosion does not occur ordinarily, due to the fact that turbulence at the steaming surface tends to rinse the caustic away as fast as it can accumulate under bubbles of steam developing on the heat-transfer surface. But anything that interferes with the rinsing process, such as a porous deposit, a steam blanket or even too many steam bubbles at some critical point, may allow caustic to concentrate and induce attack.

In the great majority of cases, caustic corrosion is accompanied by changes in microstructure which indicate overheating of the metal. Naturally, the higher the temperature of the metal, the greater the tendency for caustic to concentrate at the metal-water interface. As has been stated, temperatures in the concentrating film as little as 2 or 3 deg above saturation may, under conditions of inadequate wetting, develop caustic concentrations in the order of 5 per cent. A temperature difference of about 10 deg F could theoretically give a 20 per cent solution, or the equivalent of 200,000 ppm of sodium hydroxide, from one to ten thousand times the concentration of caustic soda maintained in most of the boiler waters throughout this country. But metal temperatures possibly 300 to 800 deg above saturation, as indicated by changes in the microstructure of the steel, are not infrequent in contemporary boilers. It certainly is no wonder that caustic corrosion, as well as hydrogen damage, goes hand in hand with the overheating of boiler steel. In fact, the authors know of no case in which corrosion did not accompany overheating of metal in contact with boiler water, unless the metal surface was shielded by a water-impermeable layer of scale. Excessive metal temperature not only invites high caustic concentration directly, but the rapid formation of steam bubbles obstructs normal rinsing to a very marked degree. In the extreme case of film boiling, virtually no rinsing at all occurs; corrosive attack is almost a certainty under such conditions.

Water-permeable deposits may play a double rôle in aggravating corrosion on steaming surfaces. How such deposits impede rinsing and allow high caustic concentrations to build up has been mentioned previously. By offering resistance to heat transfer, porous deposits increase the temperature differential between water and metal. Higher metal temperatures mean higher concentrations of alkali and greater likelihood of caustic attack. Also, if the heat-insulating effect of the deposit is appreciable, metal temperature may be brought up high enough to cause hydrogen damage or even overheating of the steel.

Tubes blanketed by a more or less continuous layer of steam are exceedingly susceptible to caustic corrosion. Fig. 5 represents a section of horizontal hair-pin tube from a 250 psi waste-heat boiler. Steam obviously blanketed the upper surface, which corroded completely through in several places. Corrosion was greatest at the apparent water level because of higher caustic concentrations there. The photograph shows part of the tube in perspective and tends to confuse the fact that the inner

Fig. 5—Gouging as a result of steam blanketing. The inner tube surface was substantially free from deposit

surface was substantially free from deposit. Microexamination of the metal indicated extreme overheating, as might be expected under the heat-insulating blanket of steam. Several other tubes were damaged in similar fashion, and a goodly proportion of the oxide produced was found in the headers and steam drum. The practical problem in this case is to obviate the evaporation on poorly wetted overheated surfaces, which results in excessive alkali concentration and consequent failure of the tube. Either a reduction in heat input, an increase in water circulation rate or mechanical changes to eliminate steam-pocketing along the top of the tube may be considered as possible means for correcting corrosion difficulties of this nature. Of course, any case of caustic corrosion can be ameliorated, if not eliminated altogether, by excluding free caustic alkalinity from the boiler water. This approach has only limited applicability, however. Most industrial plants use appreciable makeup water containing scale-forming impurities, and must therefore maintain some free boiler water caustic in the interests of scale prevention.

Corrosion Fatigue

Alternate heating and quenching of boiler steel may lead to metal fatigue, but it may also invite corrosion by rupturing the oxide coating over the metal, sometimes producing damage (corrosion fatigue) in the form of long, rather straight cracks or wrinkles. Fig. 6 represents a 1350-psi boiler tube which failed at deep cracks extending

along one side. Some distortion occurred as the tube tended to open up under pressure. Short crevices, perpendicular to the longer logitudinal ones, contributed to form a network over the damaged surface. Microscopic examination revealed severe overheating but no hydrogen damage. Minute tentacles of black iron oxide penetrated into the metal, and deposit of similar composition lined the larger cracks. Overheating, steam blanketing, alternating stresses due to quenching, and high concentration of boiler water caustic contributed to failure in this instance.

Direct Oxidation by Steam

Corrosion is sometimes possible without benefit of caustic alkalinity to attack the protective iron oxide film. Complete blockage or major obstruction in a boiler tube can cause the tube to overheat and become partly filled with highly superheated steam. A continuous insulating blanket can also develop in a tube so positioned that all steam generated within it tends to travel along the side exposed to radiation. Local "film boiling" may likewise produce temporary hot spots. But hot steel in contact with superheated steam tends to oxidize directly, producing hydrogen and a deposit of black iron oxide which usually clings tightly to the metal, often resembling anthracite in appearance, although it may be spalled off by repeated quenching as water strikes the overheated metal.

Much has been said in preceding sections concerning the accelerating action of concentrated caustic upon the corrosion of heat-transfer surfaces. If the presence of caustic in the boiler water can lead to aggravated damage where the boiler water concentrates, then why not eliminate the caustic and operate with captive alkalinity or with "pure" water containing as little as possible of any dissolved substance? Either of these expedients will slow down the attack, but may not prevent it if the thermal conditions are severe, as has been demonstrated conclusively in a number of cases on record. On the other hand, the beneficent aspects of caustic at the low concentrations normally carried in boiler water must not be forgotten. Meeting the specific problem in a specific boiler is then a matter of engineering judgment not unlike that of a physician who must decide whether his patient requires surgery or may be helped adequately by medicine.

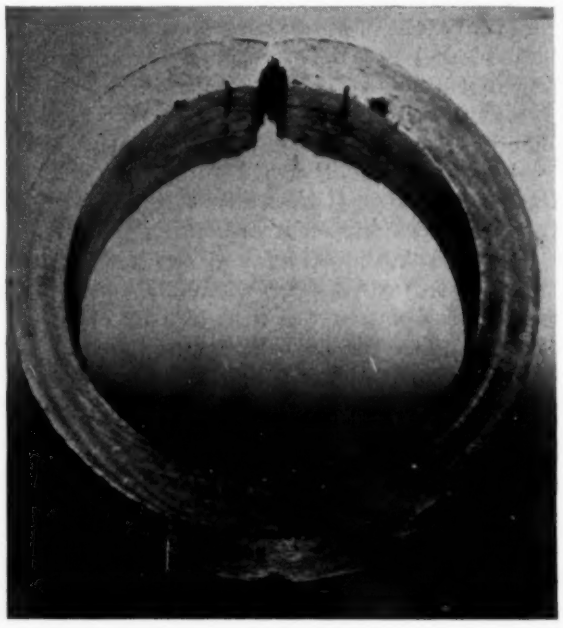

Fig. 6—Failure characteristic of corrosion fatigue

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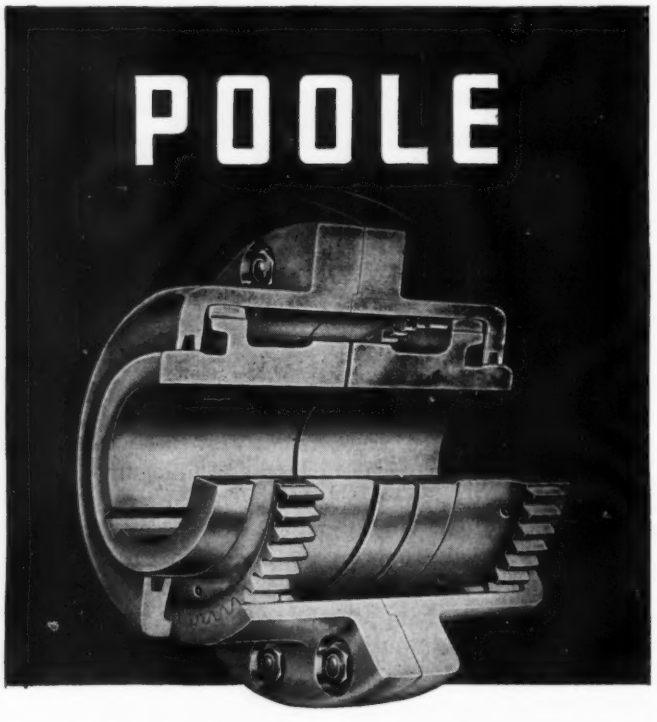

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FLEXIBLE COUPLINGS

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Labor Saving in Small Boiler Plants Through Modern Equipment

By CARL E. MILLER

Combustion Engineering-Superheater, Inc.

The following notes are abstracted from a paper presented at the Eighth Annual Anthracite Conference held at Lehigh University, May 4, 1950. By reviewing the opportunities for installing modern labor-saving equipment in small and medium-size industrial boiler plants the widely held opinion that fuel oil burning means less operating labor is controverted.

THERE is little doubt of a feeling that coal-fired boiler plants require more operating labor than those burning oil. Whether there is any foundation for such a belief is open to question, when a well-designed and well-operated plant is considered.

It cannot be denied that more labor is often employed for operating a coal-fired installation, but this is frequently due to lack of modern labor-saving devices or failure to use them properly. Many anthracite-burning plants lack even the simplest devices for moving coal from the storage bin to the stoker hopper; others have modern equipment but have failed to realize the possibility of reducing the operating force accordingly. Sometimes, possible reductions in manpower are recognized, but changes cannot be made because of certain local regulations that require a man for each of a number of different jobs.

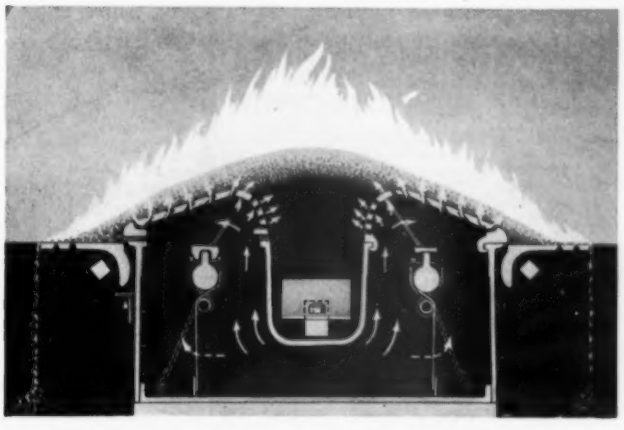

Fig. 1—Ash-removal with small underfeed stoker burning anthracite

In many older industrial power plants of both small and medium size, labor-saving devices such as coal- and ash-handling equipment, feedwater regulators, reliable stokers, and automatic cinder disposal systems were not available; and it was general practice to have one man as water tender, a second to fire the boiler, a third to supply the coal (often by wheelbarrow), and a fourth to remove ashes and keep the plant clean. With modern equipment all these functions can be consolidated into one-man operation.

An initial requirement for a properly designed anthracite-burning plant equipped with adequate labor-saving devices is a suitable stoker. For such plants two types of stoker are best adapted. For the small plant it is usually a single-retort, underfeed type having screw feed and equipped with automatic combustion control to regulate the rate of coal feed and the quantity of forced-draft air supply to suit the load. When burning anthracite on such a stoker the resultant ash is fine and usually free from clinkers, so that the refuse can be removed automatically without difficulty. With the combination of automatic combustion control and continuous ash removal from the fuel bed (see Fig. 1) the only manual labor necessary is that for cleaning of the ash pit once a day, or once a shift. Such installations generally have capacities up to about 10,000 lb of steam per hour.

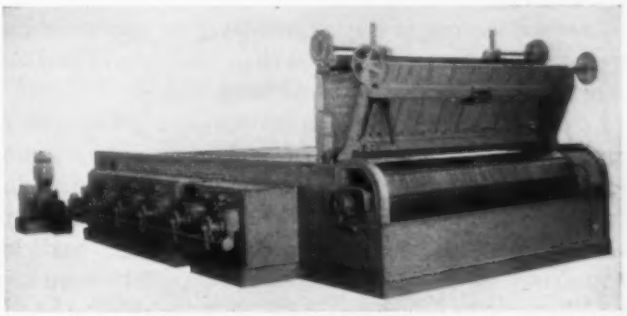

Fig. 2—Shop assembly of traveling grate stoker showing method of collecting cinders and regulating depth of fuel bed

Above this range of capacity the traveling grate stoker is the usual choice for burning anthracite. Fig. 2 is a shop assembly view of such a stoker, which incorporates the automatic method of collecting siftings from under the grate.

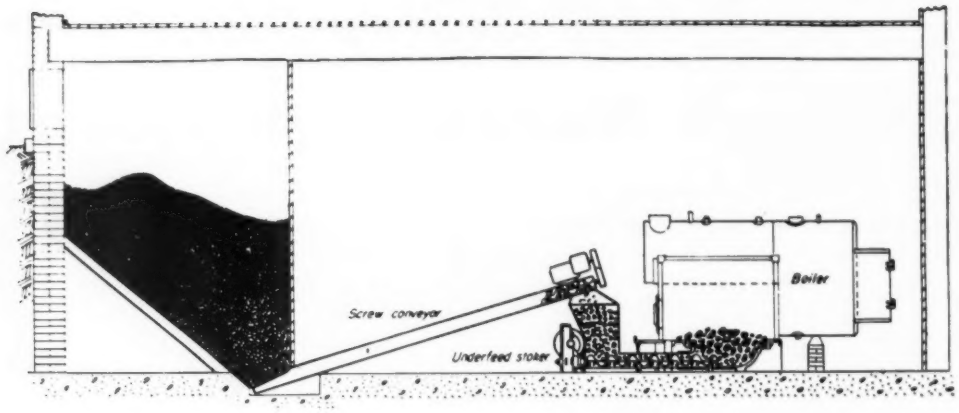

Fig. 3—Screw conveyor for feeding stoker hopper

As one may recall, not too many years ago the procedure for collecting the siftings was to draw them manually out onto the floor and then shovel them into a wheelbarrow for disposal. This is now replaced with the mechanism shown which consists of screw conveyors in each windbox section, traversing the entire width of the stoker. These conveyors move the siftings to the outside of the stoker where they are discharged to a collecting conveyor. This, in turn, transports the material to a point at the rear of the stoker for disposal or for return to the furnace. A single motor drives the entire mechanism.

Another feature is the adjustable gate mechanism at the front for maintaining the desired thickness of fuel bed to suit the particular size of coal being burned.

In the earlier installations of traveling grate stokers burning anthracite, difficulty was sometimes encountered with ignition of the incoming fuel. In modern installations this problem has been solved by use of a long rear arch. With this construction the fine particles blown from the rear of the grate are carried forward and deposited on the incoming fuel. This, in addition to the reflected heat from the arch and the flow of hot gases toward the front of the stoker, assists in maintaining ignition. At high ratings, the increased air flow increases the effect at the front of the stoker so that even more effective ignition is obtained. Thus the rear arch serves both to assure mixing of the combustion gases and to assist ignition of the incoming fuel.

Another important factor, if operation is to be carried on with a minimum of manpower, is adequate coal- and ash-handling equipment.

One of the simplest methods for a small plant burning a few hundred tons of coal per year is an overhead larry for the coal and refuse containers for the ash. Such a plant of about 450 hp, consuming around 500 tons of anthracite annually, would require only about $2^1/_2$ hr of actual operating labor daily.

Another inexpensive method of keeping the stoker hopper full, if the bunker is opposite the boiler, is through use of a small screw conveyor. Such an arrangement is indicated by the sketch in Fig. 3.

Equipment for Larger Plant

For the larger industrial plant consuming around 1000 tons of anthracite annually, bucket elevators, screw conveyors and mass conveyors are often used. Fig. 4 shows a combination bucket elevator and screw conveyor. By using hopper switches to start and stop the conveyor, this arrangement can also be made completely automatic and the total cost installed should be approximately $4000, at present prices.

Where the bunker is opposite the boiler, a mass conveyor is often applicable. Fig. 5 shows this type of conveyor. It consists of an enclosed casing through which conveying flights travel. Coal moves upward and forward with the flights in a solid column to the point of unloading at the top of the chute which then carries the coal by gravity to the stoker hopper. Such a conveyor is dustless and flexible in application, as it can be loaded or unloaded at any point. Its cost for a typical small plant is about $3000.

Another possibility, within this range of boiler capacities, is use of a bucket elevator arranged so that both coal

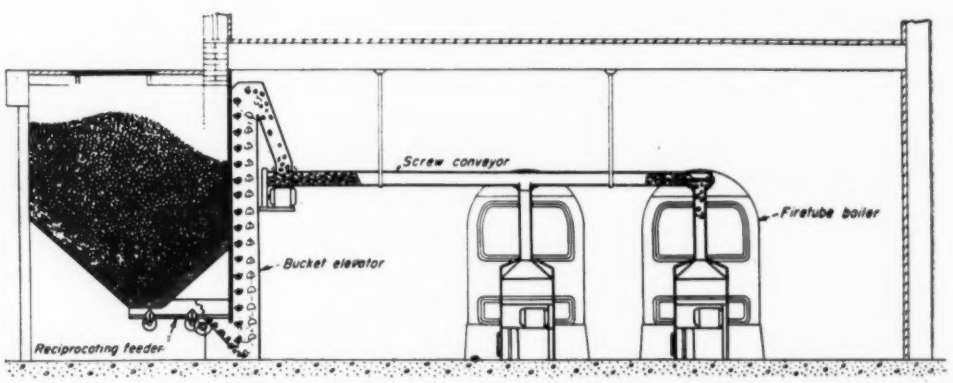

Fig. 4—Combination bucket and screw conveyor

and ash can be handled by the same conveyor. That is, when handling coal the buckets are loaded at the bottom of the hopper and move up and across the overhead bunker where they are dumped and return to the point of loading by making a complete circuit. When coal is not being handled, ash can be removed from the hoppers

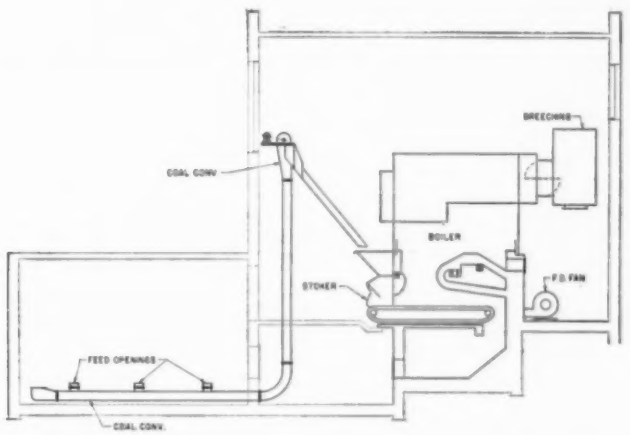

Fig. 5—Application of a mass conveyor

under the stokers, loaded into these same buckets, and elevated to the top of the plant where they are unloaded into an ash-storage bunker. From here the ash can be discharged to trucks, as desired. One of the advantages of providing such an overhead ash-storage bunker is that it facilitates sale of anthracite ash which is usually in demand for the manufacture of building blocks in many localities.

In the larger plants, use of the pneumatic type of ash-handling system is common. It has the advantage of cleanliness and simplicity of working parts, and is particularly applicable to handling anthracite ash, as large clinkers rarely occur. However, it is more expensive to install initially than are any of the previously described systems.

Facts and Figures

Bars of iron over a foot long were once used as currency in England.

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The first steel pipe was made by screwing together old musket barrels.

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Conservative estimates place petroleum reserves in the Middle East about equivalent to those in North America.

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Solar energy has been calculated as equivalent to about 5000 hp per acre at noon.

•

Fission of a kilogram of uranium 235 is said to equal 3×10^6 times the energy released by combustion of the same weight of coal.

•

Steel plants in the United States can produce almost as much steel as the rest of the world put together.

•

Modern large steam generating units are usually designed for an overall draft loss of 6 to 8 in. A large portion of this is taken up by the air preheater.

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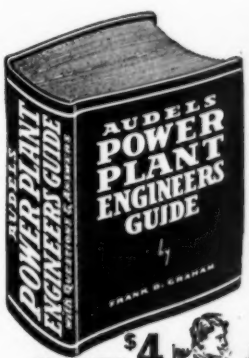
Replacement of a part of the cement with fly ash increases the resistance of concrete to the action of freezing and thawing.

Terrell H. Walker Passes

Terrell H. Walker, manager of the Service and Erection Department of Combustion Engineering-Superheater, Inc., died at Roosevelt Hospital, New York, on June 9, after an extended illness. He was 65 years old and widely known in the engineering field as an expert on in-

stallation, starting up, and operation of power plant equipment.

A native of Virginia and a graduate of Virginia Polytechnic Institute, his earlier connections included General Electric Co., Narragansett Electric Co. of Providence, R. I., Stone & Webster Engineering Corp., Dwight P. Robinson, Inc., and United Engineers & Constructors. He joined Combustion Engineering in 1936. Surviving are his wife, Beatrice S. Walker, and a son, Terrell H. Walker, Jr.



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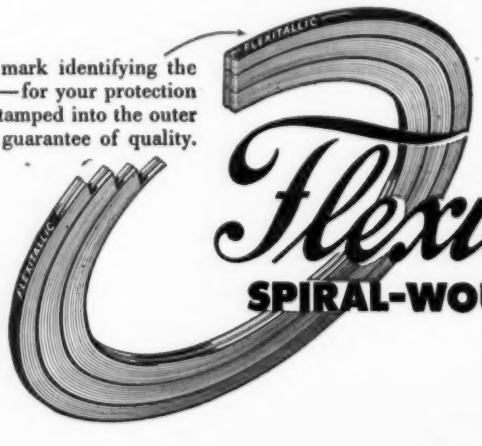

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Trends in Steam Plant Design

By PAUL E. GOURDON

Chief Mechanical Engineer
Ebasco Services, Inc.

This paper, which was presented at the recent Midwest Power Conference in Chicago, reviews objectively some of the more significant and outstanding trends in the engineering and design of modern steam-electric generating stations, with particular reference to achieving a balance between all the variables involved.

THE utility industry justly prides itself on the high quality and reliability of the service it renders, in the face of mounting investment costs, increased fuel, operating and maintenance expenses, and limitations imposed upon the rates that can be charged for the service rendered.

Under the impact of a number of factors, many of which are economic in character, there has come about a change in the thinking of power engineers. This has resulted in new ideas that make it possible for management to effect economies in specific situations. It is true that some trends are brought about from a desire to contribute to development of the art, but these instances are few, even when founded, in some degree, upon economic justification on a long-range view.

There is not unanimity of agreement among engineers and management as to the economics of some trends. Nonetheless, the increasing number of installations incorporating new features, and the satisfactory experience with them, suggest a close scrutiny of their merits.

Unit Installations

High availability, together with improved reliability of steam generators, has expanded the use of the unit type of installation in which a single turbine-generator is served by a single steam generating unit. This principle is frequently extended so that in multiple installations, no interconnections are provided between the unit arrangements. Substantial savings in investment, as well as a decrease in operating and maintenance costs, are thereby realized.

Some engineers feel that a case can be made for two boilers per turbine-generator and, perhaps, interconnection between groups. Undoubtedly, some situations justify the added expense, but assumptions made as to outage and other conditions have a substantial bearing on the results.

There is no ready answer for the problem of a limiting size of steam generator beyond which the unit arrangement might be considered hazardous; the decision will depend on specific conditions.

The Outdoor Plant

Practice and experience in the oil and chemical industries pointed the way to the semi-outdoor type steam-electric station, especially where climatic conditions did not require the complete protection afforded by a conventional building. As time went on, more and more of the enclosing structure was eliminated, and today there are in successful operation many types of semi-outdoor and outdoor steam plants.

This type of design received strong emphasis during the war, because of the need to conserve materials. An additional accelerating factor has been the high cost of structural materials and other construction costs. Although new problems, relating to weather protection and freezing, were created, adequate solutions have been developed and are under further study for refinement. Increasing use of this type of plant has led manufacturers to re-examine their own designs, with the result that substantial progress has been made in the adaptation of their equipment for all-weather use.

There is no general answer as to how much the outdoor type of plant will save, as each case must be analyzed in relation to its own influencing factors, such as site, foundations, climatic conditions, economies of circulating water system, degree of isolation of the plant, etc.

In analyzing the merits of such design, it must be kept in mind that the traditional building requires substantial maintenance, and the presence of a building inclines designers to find use for the volume made available. The addition of floors, platforms, stairways, additional lighting and ventilation, all add to the total cost and housekeeping is expanded. Also, apart from the economy in structures, there are savings in piping runs, conduit runs, and other miscellaneous plant elements.

A number of such plants have been through winters, sleet storms, heavy rains and hurricanes, and their behavior has justified the use of this design.

Centralized Control

Use of a centralized control room is meeting with increased favor among engineers and operators. The almost completely automatic operating characteristics of a modern steam plant and its development into a so-called "push-button" plant lends itself very well to centralized control. It takes more highly skilled personnel to operate the present-day power plant, and the imperative need of keeping down operating costs further justifies centralized control.

A sequel has been development of the so-called functional instrument board which requires about a third less length and no greater width than the usual walk-in board.

Cooling Towers

Only in recent years has the cooling tower established itself as an important means for cooling condenser circulating water in central sections.[1] In the past, its use was restricted to small power installations, even though for many years it had a reasonably firm position in the industrial and chemical fields. The increasingly difficult problem of finding suitable power sites with adequate condensing water in certain sections of the country did much to extend the use of cooling towers.

A cooling tower entails additional losses both in capacity and in fuel; but when these are properly equated, it is found that the cooling tower has broadened the choice of sites.

Main Station Crane

Justification for a main station crane of capacity adequate to handle the largest component of the turbine-generator has come under critical study. The trend is definitely toward a capacity that will take care of any part of the turbine-generator unit, excepting the heaviest part which must be handled during erection. This results in lower cost of substructures, superstructures and the crane itself.

Some contend that should a serious breakdown occur, whereby the heaviest piece of the unit would have to be handled, much of the savings would disappear. However, experience shows such occurrences to be infrequent, and in view of the savings due to the lighter installation, management can decide whether to take the calculated risk.

Condenser Deaeration

While the use of the deaerating type of feedwater heater is well established in power plant practice, some of the larger utility companies have made effective and successful use of condenser deaeration for many years. There is a definite trend in this direction, especially in the application of the outdoor and semi-outdoor types of design. Condenser deaeration permits reducing materially certain supporting structures and this contributes to simplification and savings.

It is recognized that condenser deaeration perhaps takes away a slight degree of insurance in respect to protection against oxygen corrosion, but experience seems to justify taking this risk, if it can be called such.

Other Trends

There are significant trends in many other plant features all having as the objective a reduction in plant costs and in operating and maintenance expenses.

Decrease in the height of the turbine pedestal brings about more compactness with consequent savings in structures, piping, conduit. This advantage can be realized in any type of plant although the semi-outdoor plant has gone quite far in this direction. Some such plants have a height from ground level to top of turbine pedestal of 12 ft and utilize twin condensers; another design has a 16 ft height. A 60,000-kw installation with a conventional transverse arrangement of the condenser utilizes a height of 23 ft.

It costs money to go into the ground with structures and equipment. Hence additional pumping head in the condenser circulating-water system may be warranted as against going into the ground to maintain the customary complete siphon.

Because of the increased reliability of fan equipment more installations equip the steam generating unit with a single forced- and a single induced-draft fan.

Variable-speed couplings for driving boiler feed pumps and fans are increasing in use. However, their economics are rather close, and some problems remain to be resolved in the smoothness of their operation. It is believed that something might be done in lowering their initial cost.

In the conventional type of power plant having the usual building enclosures, the arrangement of the so-called auxiliary and pulverized coal or bunker bay has resulted in blending these two together with consequent reduction in the overall dimensions of the building. The resulting arrangement is better coordinated and facilitates centralization of accessories with corresponding decrease in length of piping, duct work, conduits, power and control wiring, etc. The unit arrangement influenced this change.

The extended use of welding and improved and more reliable piping materials are contributing to the justifiable elimination of duplicate piping systems wherever reliability is not impaired. Great care should be given to location of equipment for accessibility and maintenance, such as is conducive to good housekeeping.

Steam plant design has kept pace in providing more congenial atmosphere for its highly skilled operating personnel, with heating and ventilating systems which result in substantially higher investments. However, there is room for much study to the end that these features may be applied economically to the modern power plant. In some localities where climatic conditions justify it, air conditioning is considered worth while and is installed in those areas where the operating personnel are likely to be located for long periods, as in the centralized control room.

The Model as an Engineering Tool

The three-dimensional model has considerable merit not only in facilitating the exposition of ideas but also as a check of construction designs, thus reducing engineering and design costs and minimizing field revisions.

Various uses can be made of such a model. Recently, a group of three utility companies desired to explore the possibilities of a common design for three new plants. An elementary three-dimensional model was developed having plant components movable on a scaled base. Quick decisions were reached as to the important fundamentals of the design, as the various components could be moved about and different design arrangements worked up in a matter of a few minutes.

These models are inexpensive compared to the savings possible. Apart from this, they expedite decisions particularly in group meetings, as it is more convenient to appraise the merits of a design from a model contrasted to discussions from a number of drawings representing different ideas.

[1] The author apparently refers to the United States, inasmuch as cooling towers have long been widely employed for central stations abroad.—EDITOR

Responsibilities of a Consulting Engineer*

By LESTER L. BOSCH

Project Manager, Jackson & Moreland

In considering the responsibilities of the consulting engineer, we need first to examine those responsibilities that are the basic obligations of every engineer. After these basic obligations are well understood we can then consider those additional responsibilities that are imposed upon the consulting engineer.

In this self-examination, we should ask ourselves whether our young profession is growing up to its responsibilities. Are we as individual engineers maturing? Are we taking a broad viewpoint of the problems of mankind? Are we giving our fellow men the full and complete advantage of our special training and qualifications, or are we side-stepping important responsibilities? Are we vocal, or do we allow matters that should be our concern to fall by default to the incompetent and immature, who cannot cope with them but who, unfortunately, can gain great authority and the power of decision over them? Beyond this we need ask ourselves if we are being exemplary citizens. Do we instinctively respect the rights and privileges of others?

The Engineer's Qualifications

Let us start by taking a candid look at our qualifications. Is it not part and parcel of our very nature to think in terms of the fundamental, in the basic concepts of time and space, cause and effect, of sound economics? Are we not intimately familiar with the laboring man's problem, and do we not know him in his working environment? We work with management; we worry with management; we see and understand the big and small problems facing management and all industry. Costs are continuously and indelibly in our minds. We daily face the challenging problems of competition, yet must remain professional in our approach and handling of such problems.

We as engineers have the vision to see the total dangers of the share-the-wealth philosophy, the nationalization of industry. We probably realize, too, better than any other group, the great technological opportunities that lie ahead for the benefit of our fellow men. We know hard work; we know cold facts; we are realists. We have a full appreciation of the importance of private initiative and understand well the triumphs of man when free to use his own resourcefulness. Our work is not limited by state or national borders; in fact, it extends the world around. No other profession, no other group can equal that of the engineer in richness of background, maturity of experience or potential ability to serve mankind in this larger way. No other group is more capable of keeping its feet on the ground in approaching the basic problems of our times.

Broadening Engineering

We are fundamentally honest and sincere, and have done a good technical job in designing structures and in making them inherently safe; and for these qualities we have merited and received the respect of our fellow men. But, as a profession, we are as yet in adolescent life; we have not merited nor have we received the respect of our fellow men for the satisfactory discharge of our broader responsibilities. In addition to our expertness in technical matters and our fundamental adherence to the sacred canon that the design must be safe, we need to get into broader things in larger numbers. This does not imply that we need to become politicians; but we must have the courage to challenge the warped and impractical ideas of the demagogue, to oppose those who think that by pressing a button, filling out a form, socializing industry, men can live in some Utopian existence conjured up by a regimenting state. As engineers we must take full advantage of our unique opportunity to rebuild the importance of man himself as an individual and we should act as a motivating influence to add needed stability to society as a whole.

We need to join with those relatively few members of our profession who are already performing outstanding work in the humanities and are getting that fullness of satisfaction which comes from doing for others. We need to develop a fuller understanding of the great fundamental changes that have occurred within our lifetime, of the draining of our natural resources, and the alarming dependence of the average man upon scientific and engineering miracles to solve all problems and do all work.

Professional Organization

It would be well if we as individuals were more articulate in our daily business and social lives; it would be well if we were more articulate as a profession. It is here that we as a profession face a challenging problem of our own—that of searching for and finding an organizational mechanism which will permit our profession to carry out the broader phases of its yet adolescent life. No profession can be articulate unless it is representative; it cannot be representative unless it is responsible. In this search for representation we need to deliberate fully, plan carefully and act wisely lest our real aims and purposes be defeated and our profession constrained from reaching full maturity. We must be ever vigilant lest our profession, which should be almost as universal as mathematics itself, become caught in a web of sectionalism or shortsightedness. Shallow principles have no place in the engineering profession and must be checked. The freedom and opportunity of our profession to serve industry, our fellow men and society must not be stifled by a selfish minority within our own ranks acting in concert with small caliber, "stateistic-minded" politicians.

Neither the legal profession, which by necessity must operate within areas of political jurisdiction, nor the medical profession, which unfortunately for man's welfare has been throttled artificially since horse-and-buggy days by state boundaries, can offer us a "pat" pattern. Ours is a different profession; we have different problems; we have different situations; we have different responsibilities. We must develop our own professional organization and specific codes of practice. However, we do have in common with these other great professions the concept of a professional man that requires practice with technical expertness, the highest ideals of honesty and integrity, and exemplary citizenship.

Foundations of Consulting Practice

The fundamental responsibilities we have just discussed as applying to all engineers are the very foundation upon which a consulting practice must be based. For a consultant above all must be a professional man serving himself only to the extent that he serves others first. Before he can give his best advice or counsel, he must thoroughly understand not only the engineering-economic problems confronting the client but, just as important, the client's own situation as well. Then, having understood, he must protect his client with strict professional confidence. Being a professional man, he cannot engage in fee or price competition with his fellow consultants. On the other hand, it is his basic responsibility to so conduct himself that the cost of his services to his client is kept to the minimum consistent with the best final overall result.

It will be helpful in enumerating the more important specific responsibilities of the consulting engineer if we review briefly the types of service he is usually called upon to perform. For convenience, these may be classified roughly in the following five broad categories:

1. Project work that, generally speaking, includes all or any part of the engineering work associated with a prospective or actual construction job, i.e., preliminary investigations and studies; design, specifications and drawings; contracts; construction supervision, job costs and inventory records; initial operation, test runs and final acceptance.
2. Process or equipment design work, which often may involve research and development, patents, trade secrets, classified government material or work and the like.
3. Professional services as a consultant, often to review operation procedures, a plan or project, or to directly assist a client within

(*Continued on page 55*)

* Paper presented at Management Session, Northeastern District Meeting, American Institute of Electrical Engineers, Providence, Rhode Island, April 26, 1950.

Continuing Metallurgical Study Produces Major Savings For Utilities

BACK some ten years ago, Kellogg's metallurgists, working with the turbine manufacturers, discovered that carbon-moly steel, which had been "killed" with less than half a pound of aluminum per ton, could readily be heat-treated at lower temperature to achieve the desired uniform acicular grain size for optimum elevated temperature strength.

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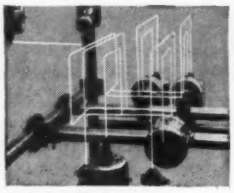

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Project work may begin with, or consist entirely of, a preliminary engineering survey or study. Such a study must be approached by the consultant with a whole-seeing, whole-thinking frame of mind. It is here he must visualize the whole problem, evaluate the overall concept and reach a fundamental understanding of his client's situation. The consultant must set a realistic period of time for the accomplishment of the study. If the assigned area under investigation proves too narrow for reaching a satisfactory solution, this he must make known to his client. Experience, plus the exercise of judgment and reasoning, must then lead the consultant to select from many possible combinations those arrangements or plans appearing to have merit. He must then study these selections in detail to understand or compare the similarity or differences between them, their relationships in time and space, and to be able to separate the trivial from the significant.

A comparison of engineering alternatives often involves painstaking chores; these the consultant must willingly accept as a basic part of his responsibility in developing the final solution. Usually in this work of selecting an engineering alternative, the consultant finds that an analysis of the incremental return on each incremental investment helps clarify an otherwise obscure differentiation.

Engineering judgment frequently plays a very important part in selection, but it is the consultant's responsibility to narrow to the minimum that area in which judgment must be applied. Likewise, the human element in the problem and performance under future business conditions must be appraised in as thorough a manner as possible.

Recommendations by Consultant

The consultant must have the honesty and courage to make recommendations as indicated by the results of his study, regardless of opinions held by others. At the same time, he must never violate the canon of professional ethics regarding the passing of judgment upon the work of a fellow engineer. If he is to avoid the embarrassing situations that can arise out of these seemingly contradictory mandates, it will be necessary for him to hew to the strictest professional principles. Above all, the consultant must never be motivated by personal interest in recommending a project that has questionable merit or which the client could better delay until a more propitious time.

Before accepting a project design assignment a consultant must satisfy himself as to his prospective client's reputation, his good intention to carry out the project, and his resources to finance it. In designing, the consultant must have the courage to make a new and bold approach, yet he must not indulge in creating a monument to himself nor, on the other hand, let his pride of original concept or a minimizing of his office cost hold him to an unsatisfactory prototype solution. The consultant must, by application of knowledge and experience, be able to improve upon and perfect the usual structure, formula, circuit, or perhaps an entire industrial process. He thus adds his contribution to the gradual process of achievement by which most of our industrial progress has been made. A consultant must insure that the design will follow the spirit of its fundamental concept and stay within the cost estimate. Should the detail design or field conditions indicate a significant departure from the agreed-upon plan, concept or cost, the consultant must immediately notify his client and reappraise his plans.

Design Considerations

It is mandatory for the consultant to continuously guard against "gold-plating" and an overconservative design. To do this, he must clearly distinguish between what is necessary for safety and what areas are subject to economic gains by the taking of calculated risks. He must subject each arrangement to a searching examination of potential failures, service outages and the like, and then determine the economic justification for duplication and the erection of various types of safeguards. He must studiously avoid burdening the design with protective features, often urgently supported on the basis of some past experience but which are not relevant or important in the case at hand.

There are, of course, many facets to the consultant's responsibility in project work that cannot be included. However, it seems important to touch briefly upon the relationship of the consultant to the manufacturer and the utilization of standardized designs. It is, of course, the consultant's obligation to keep an open-door policy to all reputable manufacturers and to avoid, wherever possible, discrimination in the preparation of specifications. Bids, too, must be received with an open mind and with professional courtesy. A consultant must studiously avoid becoming obligated by accepting, from a manufacturer, service or technical assistance beyond what is reasonable and proper. Every consultant must be aware of the importance of promoting standardization, yet he must be ever vigilant to detect standardization trends that are primarily and essentially for the benefit of the manufacturer but are a disadvantage to the ultimate user. All standards should be well coordinated and integrated with other standards if they are to stand the test of time.

In the field of process or equipment design, the consultant must be prepared and able to supplement, and to implement, the newest discoveries and developments of the scientist so that these are turned to practical usefulness for mankind. In this sphere the engineer is pushing forward the frontiers of both science and engineering.

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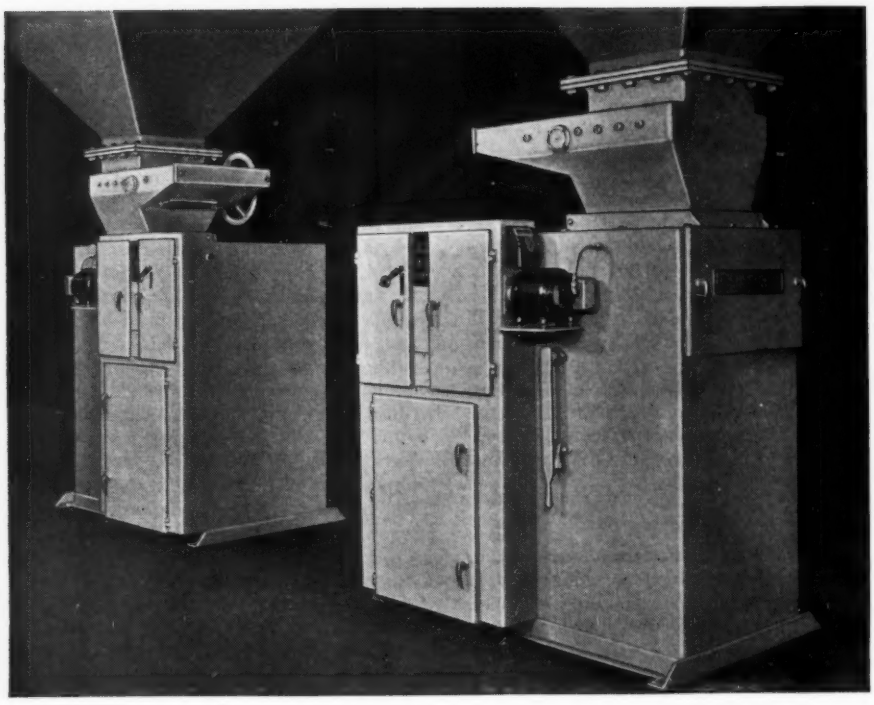

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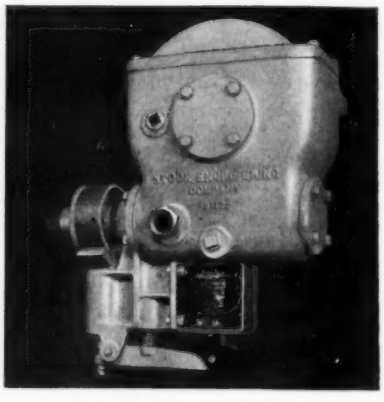

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to assist a client within the framework of his own organization or to review a specific plan or proposal has, of course, in the last analysis the basic responsibility to provide his client with good sound engineering advice. This must be developed through a fresh, vibrant yet cooperative approach, a full and mature understanding of his client's situation, and a harmonious association with his responsible personnel.

The dominant responsibility of a consultant when serving as an expert engineering witness or in appraisal and valuation work is more than that of developing and presenting an honest, fair interpretation of the facts according to the law or regulation which applies. It is rather a serious weighing of issues in which the professional integrity, the interest of his client and a fairness to the question at hand must all be reconciled in his conscience.

Many broad overall problems fall within the scope of an engineer's responsibility when he acts in the capacity of an adviser to an investment house or governmental authority. In such a capacity, the engineer may often be standing upon the frontier of his profession, wielding an important influence in decisions of the greatest magnitude. Frequently he must deal entirely with laymen who hold key posts of government or finance. The engineer in such surroundings must hold fast to his professional principles, fundamental engineering-economic thinking, and the broadest overall concepts of human dignity.

Conclusion

It might be said that the basic responsibility of all engineers is that of exemplary citizenship, service to mankind, and sound thinking in relation to the problems of our times. They must be ready and willing to challenge immature and irrational thinking wherever encountered and unselfishly give moral and financial support to technical and professional society activities, thus assuring to themselves and the engineering profession the role of serving mankind in the fullest sense. The extent to which the consulting engineer, in his daily work, visualizes and comprehends an engineering-economic problem in its entirety, understands his client's particular situation, has the courage of his own convictions, is fair and honest, and practices his profession with technical expertness is the extent to which he will live up to his obligations to his client and reap the reward of complete satisfaction.

N.A.P.E. to Meet in St. Louis

The Sixty-seventh Annual Convention of the National Association of Power Engineers will be held in St. Louis, Mo., from August 15 to 19 at the Hotel Jefferson in conjunction with its Annual Power Show. Highlights of this year's show, in addition to more than 100 exhibits, will be an industrial movie program, educational meetings featuring addresses by nationally known experts in the field of power, and round-table clinics.

Some Highlights of the Federal Air Pollution Conference

A résumé of the Legislation Panel held during the three-day U. S. Technical Conference on Air Pollution, which took place in Washington, D. C., May 3-5. Other features of the whole program, not here reported, included an historical review, health hazards, effects on plant life, cost of air pollution, means for determining air contaminants, control through equipment and other means, and governmental action.

REPORTING on "Problems in Drafting and Administration of Air Pollution Control Legislation," **Arthur C. Stern,** of the New York Department of Labor, was of the opinion that control of atmospheric pollution poses a different problem for each community, depending upon the fuel available, the nature of local industries and the topography of the region. Moreover, stack emissions that give acceptable color or density values, by the Ringelmann Chart, may still cause a nuisance from dust. The measure of such emission should be the weight of dust per cubic foot of gas measured at standard temperature and excess air.

Dust from sources other than the burning of fuel is more difficult to evaluate and regulate, the suggested criterion being the amount of dust discharged in pounds per hour related to the quantity of product produced. Stack height is also a factor.

Mr. Stern believed that regulations should provide for the approval of plans and the licensing of new installations; whereas existing installations should be subject to inspections for approval of operation. Penalties, he suggested, should consist first of threats of fines, jail terms and the shutting down of plants, where conciliatory efforts fail. Fines should be severe enough to discourage any thought that it might be cheaper to pay them than to correct conditions.

Abuse of authority should be guarded against by providing an Appeals Board.

Federal assistance should be limited to supplying research information.

Pittsburgh Situation

The situation with regard to Pittsburgh was discussed by Messrs. **German, Rose, Eichenauer** and **Stewart.** Here the smoke problem is the result of high concentration of industry, a large population, unfavorable topography and bituminous coal.

The first effort to obtain cleaner air in Pittsburgh dates from 1880 when a smelter was enjoyed by court order from creating a dust nuisance. A succession of ordinances of increasing stringency followed, some of which were invalidated by the courts.

An enabling act was passed in 1917 providing for county jurisdiction and within the county cities of second class were also given power to enact ordinances that may be stricter than that of the county. The present Pittsburgh ordinance is similar to that in St. Louis, in that use of bituminous coal is banned unless burned by mechanical equipment. There is differentiation between new and old installations as the former must comply fully with the regulations, whereas the latter must comply to the fullest extent possible where strict enforcement would result in closing the plant.

With further reference to Pittsburgh, **A. X. Alpern,** city solicitor, stated that no real progress in the abatement of atmospheric pollution had been made until the public was aroused, and that during the last ten years an educational program had been carried on principally through the aid of newspapers and had thereby advanced the cause more than had the previous 40 or 50 years of attempted legal pressure. Violations average 1675 per year, most of which are settled amicably, with only 16 being taken to court. Retail fuel dealers are licensed; new installations must be approved and old plants inspected yearly; but no license is required for plant operators. Costs of inspections are levied against the plant owners.

California legislation

"The Legal Aspects of the California Air Pollution Control Act" were reviewed by **H. W. Kennedy,** county counsel of Los Angeles County.

Increasing growth of population and establishment of many industries have resulted in a serious air pollution problem, the control of which was attempted by enactment of a "model smoke law," which 44 cities in the county adopted, but a trial of $1^1/_2$ years proved it unsatisfactory as each community had its individual problem.

The present 1947 California Air Pollution Act provides for a control district in each of the 58 counties of the state. It also provides for legal machinery with teeth, adequate financing, an alerted citizenry and cooperation from industry. Administration in each district is under a board of supervisors selected from county officers and a Hearings Board is set up for control and enforcement. This board is composed of three members, appointed for three years, and consists of two lawyers and an engineer. Permits are required for the construction and operation of plants, with approval of plans necessary in the case of new plants. Orchard heating and other agricultural activities are generally excluded. Functions of the Hearings Board were described in some detail by **H. V. Walker.**

Discussion which followed the papers by Mr. Kennedy and Mr. Walker questioned the permit system and the rights of inspectors to have free access to plants, especially where secret processes may be involved; but the authors regarded the permit as vital and plant inspection as necessary, adding that the inspectors have the necessary ability and experience to pass on technical processes. Where corrective measures are prescribed, they are the joint responsibility of the company and the air pollution control body. However, the A.P.C. has no legal responsibility. Where it is certain that the process will comply, a permit is issued; and where uncertainty exists a temporary permit, subject to test, is given.

As to the specific limits of emission under the Act, the following standards were cited:

Smoke density—less than No. 2 Ringelmann
Sulfur dioxide—0.2 per cent by volume
Particulate matter—0.4 per cu ft standard gas

For dust from non-fuel sources, limits have been set in the permissible quantities in pounds per hour, graded according to the amount processed. These limits start with 0.852 lb per hr for 200 lb per hr of processed material up to 40 lb per hr for a 60,000-lb process load.

St. Louis Situation

"The St. Louis Code and Its Operation" was the title of a paper by **R. R. Tucker** of Washington University, St. Louis. He gave a brief review of attempts at air pollution control in that city, dating from 1864. No real progress, however, had been made until 1933 when an ordinance was passed giving complete control over fuel burned within the city. This includes a clause providing that coals be washed to a quality equal to the face analysis of the seam. The original ordinance exempted home owners, but later amendments provided that no class of fuel users would be exempt and restricted permissible fuels to less than 22 per cent volatile unless burned by mechanical equipment. All equipment must pass inspection and dealers are licensed. Provision was made for relaxation of the rules to cover emergencies.

R. L. Hansen, of the Manufacturing Chemists Association Legal Advisory Committee, took a stand against the license system for either the construction or the operation of plants, on the grounds that the granting of a license was no assurance of compliance with the statutes. Instead, he contended that industry should be given limits to which they must conform and should have the full responsibility of devising the necessary methods. He conceded that regulation of atmospheric pollution is necessary, but believed it should be recognized that control is a local problem to be handled by municipal and county organizations.

Control in Britain

Discussing atmospheric pollution and methods of control employed in Great Britain, **W. A. Damon,** chief inspector of alkali works for the city of London,

traced real efforts to the Alkali Act of 1863, which was aimed at abatement of conditions brought about by the manufacture of soda by the La Blanc process, in which hydrochloric acid was discharged as a by-product. Under this act, which now applies to all fumes, the present limits of emission are as follows:

Soda works—HCl, 0.2 gr per cu ft
Lead chamber process—SO_2, 4 gr per cu ft
Sulfuric acid concentration—$1^1/_2$ gr per cu ft
Hydrochloric acid works—12 gr per cu ft

The smoke abatement act was passed in 1926 and under it emphasis is placed on sulfur dioxide. While washing with lime has been employed at Battersea power station and with ammonia at Fulham, these methods are expensive and the former presents a problem of stream pollution. Also, there is some question as to whether a cool wet gas with a trace of SO_2 might not prove a greater nuisance than a dry gas of higher SO_2 content.

There are only six inspectors for the whole of England and Wales.

Federal control not advisable

"National Aspects of Atmospheric Pollution Legislation" was the title of the final paper and was presented by **J. L. Hofflund,** chief counsel of the U. S. Bureau of Mines, who saw no indication of the necessity of such control on a national basis. There is, however, a broader aspect to the problem where in certain localities international cooperation with Canada may be involved. Also, the possibilities of atomic power application may constitute a world-wide problem where local powers may not suffice.

Furthermore, the Federal government can aid and, in fact, is aiding in the form of technical research through the Bureau of Mines; and the Public Health Service is also available in an advisory capacity.

Conference on Heat Transmission

Post-war heat transfer development will be the theme of an international discussion to be held in London, September 11 to 13, 1951. Plans for participation by engineers in the Western Hemisphere are being arranged by the Joint Committee on North American Participation, which consists of representatives from The American Mathematical Society, American Institute of Chemical Engineers, The American Chemical Society, The American Society of Refrigerating Engineers, American Society of Heating and Ventilating Engineers American Society of Mechanical Engineers, American Institute of Physics, American Institute of Mining and Metallurgical Engineers, The American Physical Society, The Society of Automotive Engineers, The Institute of the Aeronautical Sciences, and The Engineering Institute of Canada.

The American Society of Mechanical Engineers is coordinating administrative details.

Participation by British and European engineers is being coordinated by the Institution of Mechanical Engineers with the cooperation of 30 British societies and the engineering and technical societies of Australia, India, New Zealand, South Africa, Belgium, Denmark, France, Holland, Norway, Sweden and Switzerland.

Preliminary plans indicate that the following subjects will be among those discussed: recent information on physical properties of gases and gas mixtures pertinent to their heat transfer characteristics, measurement problems related to heat transfer, mass transfer and heat transfer by sweat and film cooling, condensation at high speed flow, heat transfer to liquid metals, and the analogy method for the solution of conduction problems.

Electric Output Figures

Production of electric energy by utilities during April totaled nearly $25^1/_2$ billion kilowatt-hours, the highest April output on record and exceeding that of April 1949 by 9.6 per cent. Of this, hydro accounted for 32.6 per cent—a decrease over last year—and fuel-burning plants produced over 17 billion kilowatt-hours.

The April 1950 coal rate averaged 1.19 lb per kwhr, as compared with 1.23 lb a year earlier; and the consumption of coal and coal equivalent of other fuels showed an increase of 10 per cent over April 1949, compared with an increase of 13.8 per cent in total fuel generation.

Natural gas consumption was up 17.5 over a year earlier and fuel oil 35.9 per cent. In fact, the April 1950 oil consumption of 5,319,423 bbl was the highest on record for this season.

Stocks of coal on hand at electric utility power plants, as of May 1, totaled over 18 million tons, which was an increase of 17.6 per cent during the month. Oil stocks, based on April use, were sufficient for 48 days.

For the 12 months ending April 30, 1950, electric utility production was 298,104,943,000 kwhr, which represented an increase of 3.8 per cent over the preceding 12 months.

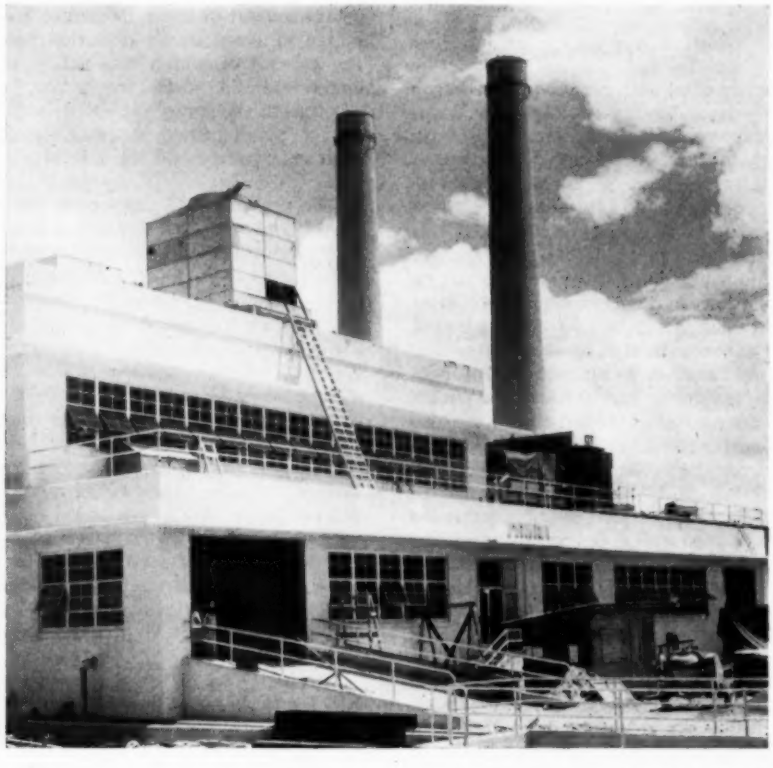
Increase in installed generating capacity during the month of April 1950, as reported to the Federal Power Commission, was 701,906 kw, bringing up the total installed electric utility capacity, as of May 1, to 64,562,324 kw.

Industrial power plant production during April was reported as 4,754,248,000 kwhr, or an increase of 4.9 per cent over that of a year earlier. The total industrial electric generating capacity was 13,523,843 kw.

New Power Plant for Puerto Rico

A new 14-million dollar steam plant is being constructed in the San Juan area of Puerto Rico to amplify the power facilities of that island. Plans call for the initial installation of three 20,000-kw units, the first two of which are expected to be in service by next January, although provision is being made for an ultimate capacity of 100,000 kw.

The plant is being built as part of a program of The Puerto Rico Water Resources Authority to meet increased electrical demands by large-scale housing developments and industrial establishments.



Hamilton Wright

Recent construction view of new power plant at San Juan

Report of Progress in Peat Burning

CONCERN with development of a natural fuel to aid the growth of industry in the state of Minnesota led to the establishment of a research laboratory at Chrisholm, Minn. One of the objectives was to make studies and devise means for utilizing the enormous peat reserves of that state in order to obtain a low cost fuel for the production of electric power. The Office of the Commissioner of Iron Range Resources and Rehabilitation has recently published a preliminary study by Clayton E. Plummer entitled "Report of Progress in Peat Development," from which the following is abstracted.

By definition peat is an accumulation of partly decomposed plant life, especially mosses, varying in consistency from a fibrous matted material to a highly decomposed mud, generally having a moisture content of 88 to 93 per cent. There are at least four kinds of peat:

1. Lake peat is a sticky, plastic or pulpy sedimentary mixture made up of decomposed plants mixed with clay and sand, occurring at the bottom of filled-in lake deposits.

2. Lowland peat is generally a second stage of marsh growth consisting of partially decomposed remains of lake shore plants.

3. Upland peat is composed largely of live and partially decomposed sphagnum mosses and heath.

4. Forest peat consists of the accumulation of dead leaves, wood and trees, together with sphagnum mosses and heath.

It is estimated that the total quantity of peat in Minnesota occurring in deposits five feet or more thick, assuming 200 tons of air-dry machine peat per acre per foot of thickness, is approximately 6,835,300,000 tons. The total area of 7,000,000 acres of peat lands in the state is believed to represent approximately 50 per cent of the peat in the United States.

Machine peat refers to processes of producing desirable qualities in a peat fuel by converting it into a compact and durable form. There are six fundamental operations necessary in the production of machine peat: (1) excavation, (2) maceration, (3) forming, (4) transportation, (5) spreading, and (6) harvesting. In some cases the peat is formed immediately after maceration and is transported to the drying field as blocks, while in others the peat is transported to the drying field after maceration and is then formed into blocks.

Milled peat is produced by fully mechanized operations without the use of maceration. A layer of peat about one-half inch is cut from the surface of the bog in a finely divided condition and dried on the bog near where it was cut. In Ireland milled peat is extensively used in the form of briquettes as a domestic fuel.

Hydro peat is produced by cutting the peat with a stream of water and pumping it to drying fields where it is later cut into blocks. This method is particularly applicable where water and electricity are available and when the bog contains a large proportion of timber and roots. The Russians produce a great deal of peat fuel for power by the hydro peat process, approximately one-fourth of their 1947 production of 31,140,000 tons being produced in this manner.

As it comes from the bog, peat has no net heating value, since all of the heat available by burning the peat would be consumed in evaporating its moisture content. Dried peat has a heating value of about 8850 Btu per pound, which compares favorably with lignite. By comparison with coal, peat with 25 per cent moisture has about half the heating value and twice the volume of an equivalent coal weight. It has nearly twice the volatile content of average bituminous coal (including more than three times as much oxygen) and about half the fixed carbon. To burn peat a furnace volume about four times that required for coal would be necessary to produce the same heat liberation. Also, as a result of the high per cent of volatile matter, the flame produced when peat is burned is much longer than that from coal. Because of the light weight of the peat particles it is necessary to increase the forced draft beyond that used in coal-burning practice when it is desired to burn peat in a finely divided state or in a spreader stoker.

In 1914 at the Klasson power station.

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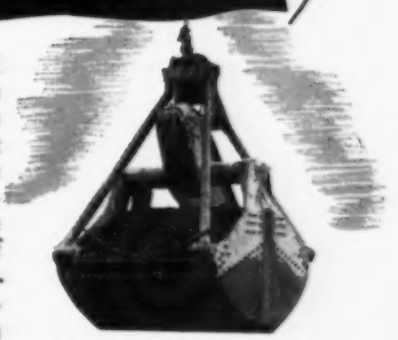

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70 miles east of Moscow, the Russians were said to have burned peat on a large scale in a boiler furnace. However, boiler efficiency was very low, and it was not until the Makarev shaft-chain grates were tried at the 136,000-kw Shatura station in 1921 that peat was burned at a claimed efficiency of 83 per cent. On the basis of a test run over the period of a month the results indicated an evaporation of 4.6 pounds of steam per pound of peat.

The Makarev grate is a combination of a gas producer and a chain grate in which the peat is fed down from the bunkers through the upper part of the furnace where forced heated air causes the peat particles to become incandescent. At this stage the more volatile constituents pass through the openings in the rear arch into the main combustion chamber. Into this same chamber also passes the moisture which is converted into water gas. The final burning of the peat takes place on the chain grate. The largest known plant capacity where machine peat is used is the 204,000-kw Gorgress station.

For milled peat an entirely different furnace is required, and the Russians developed the Shirshnev furnace which burns peat in suspension, operating under principles very similar to those employed in burning pulverized coal. High velocity air is injected from horizontal ports in order to maintain the furnace contents in the high state of turbulence required for successful combustion. Slag-tap operation of the furnace is desirable to minimize furnace slagging and fly-ash emission, and a high degree of air preheat is required to keep the slag in a liquid state. In the use of the Shirshnev furnace it was found that a drop in efficiency occurred with firing rates in excess of ten pounds per square feet of grate surface per hour. Heat releases of 15,000 to 17,000 Btu per cu ft per hr do not require water walls. One plant was said to have had an overall boiler efficiency of 86 per cent at a steam output of 62,000 lb per hr.

In Sweden peat has been burned in furnaces using finely ground milled peat as a pulverized fuel. Among the important developments that have been made and used in Sweden are the use of the "Whirl" and "Tornado" burners, which are quite similar to those used in the United States for burning pulverized coal. Experience with the Whirl burner has demonstrated that pulverized peat with a moisture content up to 35 per cent can be burned without the aid of a support fire at overall boiler efficiencies of 85 per cent. By mixing appropriate amounts of coal or oil, and even higher efficiency accompanied by better regulation of boiler output may be obtained.

Because of its relatively low fusion temperature (about 2150 F) peat presents many slagging problems, the solution of which may lead to the attainment of higher heat releases and more efficient combustion. One suggestion is that a preliminary furnace be developed for burning coarse particles in a suspended state in combination with a furnace of the type ordinarily found in pulverized-coal installations. The idea is that combustion gases and fines from the preliminary furnace can complete their combustion in the second furnace.

REVIEW OF NEW BOOKS

Any of the books here reviewed may be secured through Combustion Publishing Company, Inc., 200 Madison Ave., N. Y.

Kent's Mechanical Engineers' Handbook Twelfth Edition

Kent's Mechanical Engineers' Handbook, for more than fifty years a standard reference in its field, has just been published in a new, twelfth edition. This comprises two separate volumes—one on "Power" under the editorship of J. K. Salisbury of General Electric Company, and the other on "Design and Production," under the editorship of Colin Carmichael, editor of *Machine Design*. The various sections, comprising approximately 3000 pages for the two volumes, were prepared by 168 specialists in their respective fields.

It has been fourteen years since the preceding edition was brought out and there has been much advancement in practice since then, particularly in the power field. This has necessitated complete revision and expansion of the greater part of the text to cover latest practice, and much of the basic material in the eleventh edition has been condensed. Despite this the size of this volume has been increased approximately 20 per cent. A new index, carefully worked out, makes each piece of information doubly accessible.

The size and flexible binding of the previous edition are retained, and the price is $8.50 per volume.

Electrical Transmission of Power and Signals

By Edward W. Kimbark

The trend in engineering education toward the integration of related theoretical courses on the undergraduate level is reflected in this unusual text. Intended for use by junior and senior students having basic knowledge of direct and alternating current circuits, the book should also be of interest to persons outside of the field of electrical engineering who may desire to learn of ways in which fundamental transmission-line theory may be applied to the fields of power transmission and distribution, telephonic and radio-frequency communication, and ultra-high frequency transmission, including elements of television and radar.

Understanding of the book requires a mathematical background that should include elementary differential equations. There is an extended treatment of hyperbolic functions and their application to electrical engineering problems, and Bessel functions are presented in connection with an analysis of skin effect as it applies to transmission-line phenomena.

The following chapter heads give some idea of the scope of the text: Parameters of Stranded and Miscellaneous Conductors, Steady-State Phenomena on Transmission Lines, Transient Phenomena on Transmission Lines, Electric Power Transmission, Telephone and Telegraph Transmission, Radio-Frequency Transmission lines, Filters, and Wave Guides.

Considering the trend toward a high degree of centralized control in the contemporary steam-electric power plant and the application of television techniques to such problems as remote vision of water level in boiler drums, this text should be of interest to those steam-power engineers who desire to broaden the base of their existing theoretical knowledge to include the fundamental principles of modern developments in transmission lines.

There are 461 pages and the book sells for $6.

Numerical Analysis of Heat Flow

By G. M. Dusinberre

The introduction tells us that "This outstanding new book presents in a learnable, usable form, modern numerical methods for the calculation of heat flow in solids." The author also says, "This book is not adapted to casual reading. We assume that the reader has a job to do and wants to learn a new and better way of doing it."

The methods offered here would be attractive to the practical or practiced man since they combine effectively his work with the physical realities of the particular problem he has to consider. This man is more concerned with the finding of a sufficiently good answer to his question than to finding a mathematically elegant solution to problems having remote resemblances to his own particular needs.

There are numerous examples which apparently were worked out carefully and ably. Chapter XI "Numerical Analysis of Heat Flow" seems good, but some of the other chapters concern problems distinct from the power plant field.

This is a good book for anyone who requires knowledge in heat transfer analyses and has plenty of time to devote to it. An extensive bibliography aids the reader with sources of up-to-date correlated literature.

There are 227 pages and the price is $4.50.

Specifications for Steel Piping

This latest compilation of A.S.T.M. Standards on steel piping materials, as of December 1949, the book having come off press in March 1950, includes some fifty widely used specifications. Materials covered include: (1) pipe used to convey liquids, vapors, and gases at normal and elevated temperatures; (2) still tubes for refinery service; (3) heat-exchanger and condenser tubes; and (4) boiler and superheater tubes. To make the volume more complete there are also included specifications for castings, forgings, bolts and nuts, as used in piping and related installations.

There are 16 pipe specifications covering seamless and welded; electric-fusion and electric-resistance-welded and other types, in both carbon and alloy grades. Several specifications cover materials for service at high temperatures including austenitic pipe.

For boiler, superheater and miscellaneous tubes there are 13 standards, including three for stainless tubing, ferritic and austenitic, for general service and for sanitary tubing.

Three standards for seamless steel still tubes cover applications in refineries; and three other heat-exchanger and condenser-tube standards apply to seamless and electric-resistance-welded tubing of various grades.

Various classes and grades of carbon and alloy-steel castings, forgings, welding fittings and bolting are included in 13 specifications. Many of the applications are for high-temperature and high-pressure service.

The publication is made more complete and usable by inclusion of the Grain Size Standard E 19 and also by the American Standards covering steel and iron pipe (B 36.10) and the latest stainless steel document (B 36.19).

This 328-page book, with heavy paper cover, is priced at $3.

New Fan Standards

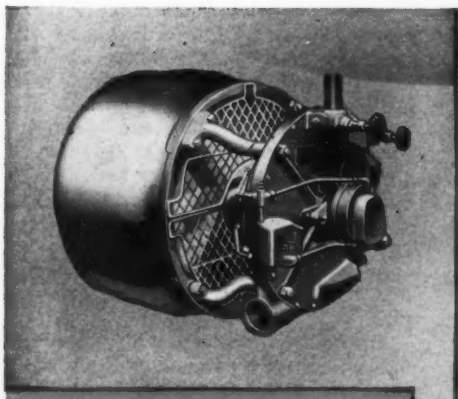
The National Association of Fan Manufacturers, Inc., has just published Bulletin 110 entitled, "Standards, Definitions, Terms and Test Codes for Centrifugal, Axial and Propeller Fans" for distribution to the public. The bulletin includes under one cover all information previously published in four separate bulletins as well as new tables on size standards for various types of fans and illustrations of revised fan arrangements. It covers the classification of air-moving equipment, standards, terms and definitions in use by the fan industry and standard codes for air and sound measurements.

This 32-page bulletin is a "must" for anyone interested in fans. A copy is available without charge on request to the National Association of Fan Manufacturers Association, Inc., 2159 Guardian Bldg., Detroit 26, Mich.

Heat-Power Symbols

A compilation of 44 Graphical Symbols for Heat-Power Apparatus has been approved by the American Standards Association as a new American Standard (Z32.2.6-1950). In preparing these many leading power companies and their representatives were consulted and a careful study was made to avoid conflicts with symbols being assembled by committees in allied fields. Clarity, simplicity, and nation-wide acceptance were basic considerations.

Sponsors of the new standard are the A.I.E.E. and the A.S.M.E. Copies of this standard are available at 35 cents each.



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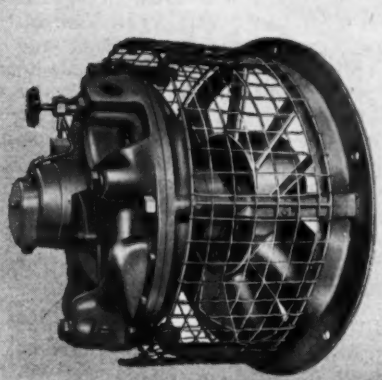

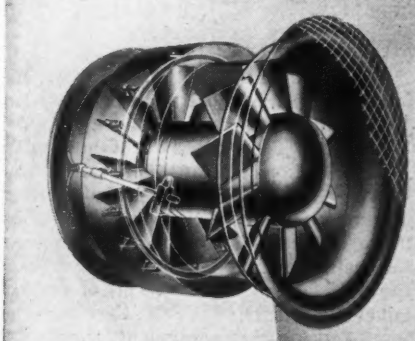

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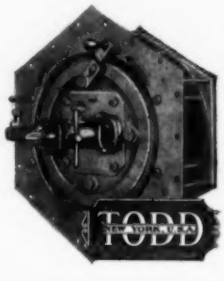

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New Catalogs and Bulletins

Any of these may be secured by writing Combustion Publishing Company, 200 Madison Avenue New York 18, N. Y.

Centrifugal Pump

An improved self-priming centrifugal pump is described and illustrated in an eight-page bulletin issued by Allis-Chalmers Mfg. Co. Capable of priming itself in ten seconds to two minutes and ejecting vapor and air in the line while running, the pump may be used in loading and unloading petroleum products, marine bilge pumping and condenser service.

Fly Ash Collector

A new illustrated bulletin by the Buell Engineering Co. provides information on the "LR" or low resistance fly ash collector intended for use in small boiler installations of limited draft. Curves of collection efficiency and draft loss are included along with general dimensions of representative unit sizes.

Synchronous Motor

An eight-page, two-color bulletin on low-speed synchronous motors has been made available by the General Electric Co It illustrates typical installations of these high-power-factor, constant-speed drives and describes their construction features as well as detailing mechanical modifications and performance data. Units covered may operate on two- or three-phase current with ratings from 20 to 15,000 hp.

Bonnet Valves

The Crane Co. has issued a new 12-page catalog which includes sizes, dimensions, ratings and tests for gate, globe, angle and stop-check pressure-seal bonnet valves for high pressure and high temperature service.

Control Linkage

A method to reduce installation costs of power-plant controls is explained in a 16-page brochure prepared by the Bailey Meter Co. As a result of flexibility in control-drive design, it is possible to standardize on relatively few sizes of control connecting linkage. The bulletin provides necessary information for choosing and ordering correct materials and arrangements to suit a wide variety of installations.

Differential Master Sender

A high-pressure type, differential master sender which may be used as the metering element in the measurement and control of steam, gas and liquid flow is described and illustrated in Bulletin 2150 just issued by the Hagan Corp. The instrument is capable of measuring pressure differentials in the range of 4 to 150 psi at static pressures up to 2500 psig.

Oil Seals

Johns-Manville has prepared a 16-page brochure containing useful data on oil seals. Photos show where to use J-M Clipper Seals and how to install them. In addition there are drawings which illustrate how the lip and seal construction of these non-metallic oil seals can be varied.

Steam Traps

A 32-page illustrated catalog prepared by W. H. Nicholson & Co. describes five types of thermostatic steam traps for pressures to 225 psig, two types of expansion steam traps for pressures to 250 psig, three types of weight-operated traps for pressures to 1500 psig, and three types of steam, air and gas separators. Capacity tables, installation diagrams, and charts for determining trap sizes for specific installations are also included.

Pressure Regulating Valves

The Swartwout Co. has issued a 12-page, two-color bulletin covering low pressure regulating valves for controlling gases and liquids. Along with photos, diagrams and line drawings there are specifications and selection data for regulating valves and pressure master controls.

Flexible Tubing

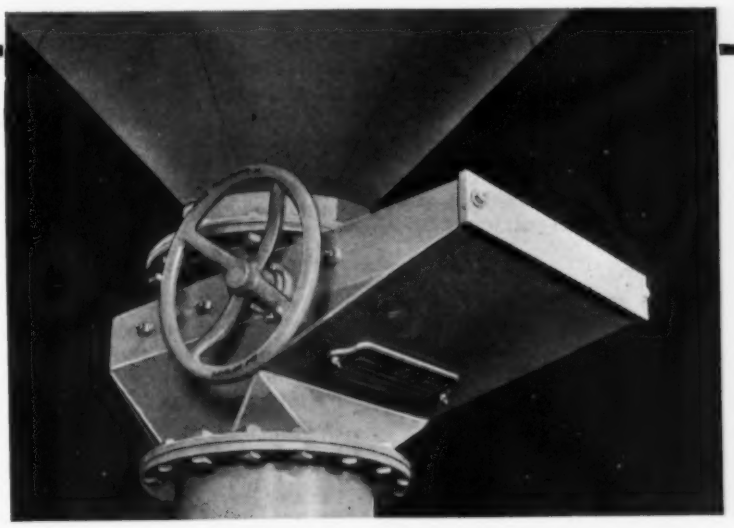
A newly improved light-weight flexible tubing which was originally developed for the Navy is now being made available to industry and is described in an eight-page bulletin prepared by the Flexible Tubing Corp. Said to be highly resistant to wear and heat, it is available in sizes from 3-in. to 30-in. ID for services ranging from a vacuum of 25-in. Hg up to a pressure of 170 psig.

Welding Fittings

An 88-page catalog on Grinnell seamless carbon steel welding fittings and forged steel flanges gives information on dimensional tolerances, American standard flange facings, thread standards and practice, service pressure ratings, and welding fittings stocked in special metals. This bulletin should prove of considerable interest to those responsible for detail piping design.

Resistance of Nickel to Corrosion

Technical Bulletin T-6, "The Resistance of Nickel and Its Alloys to Corrosion by Caustic Alkalies" has been made available by The International Nickel Co., Inc. Its 24 pages contain more than 20 illustrations and over 40 tables which explain testing procedures and give performance of nickel and its alloys in such fields as transportation, paper manufacture, and petroleum refining.



S-E-CO. COAL VALVES are equipped with U-shaped gates. This construction assures easy operation of the valves because operating racks, pinions, and supporting rollers are in a space at the side, and, therefore, moisture in the coal does not run over these parts and cause rapid corrosion and subsequent sticking of the valve.

Write for bulletin.

STOCK EQUIPMENT COMPANY

715C Hanna Building ★ Cleveland 15, Ohio

Water Conditioning

The Graver Water Conditioning Company has issued a 12-page bulletin on its Reactivator for rapid and economical water clarification and softening. Included are photographs of typical installations and flow diagrams explaining principles of operation and special applications.

Fuel Oil Treatment

A technical folder on fuel oil treatment and sludge removal has been prepared by E. F. Drew & Co. It describes the means of preventing or correcting unsatisfactory conditions in the storing, handling, pumping, heating and burning of industrial fuel oil.

Combustion Safeguard

An explanatory bulletin on the new Flame-otrol combustion safeguard for oil- and gas-fired furnaces, ovens, boilers, kilns and other heating equipment has been released by the Wheelco Instruments Co. Safety features and typical application diagram are included.

Stop Valves

A four-page bulletin describing the new 444 series globe and angle stop valves has just been issued by Edward Valves, Inc. Design details, dimensional data, material specifications and list prices are given for valves of 600 and 1500 psig classes.

Triplex Pump

The Aldrich Pump Co. has released a 6-page data sheet giving information on a new 5-in. stroke, triplex, direct-flow pump. Information presented relates to construction and design, dimension drawings, selection chart and table, and pump and drive specifications.

Dust Collectors

A 16-page booklet published by the Prat-Daniel Corp. provides detailed information on the new Valmont Type S dust collector, as well as the standard Type HC. A nomograph chart is included for determining the number of tubes required for a given capacity, temperature and resistance, and there are tables for determining dimensions of the collector for any number of required tubes.

Wired Television

Of more than usual interest to engineers is a 16-page bulletin issued by the Diamond Power Specialty Corp. and describing the "Utiliscope," a type of wired television applicable for industry and research. Advantages of using this instrument to observe continuously an object, operation or condition are explained and general specifications are included. Examples of its application to engineering testing (particularly those involving serious physical hazards), for teaching, as a technique to build sales, as a means of plant security, for observation of changes in boiler water level, and in watching furnace ignition, combustion, slag and smoke conditions are mentioned.

Steam Turbines

Bulletin 4215 of the De Laval Steam Turbine Co. contains a complete description and specifications for the new Type CP single-stage, mechanical-drive turbine suitable for pressures to 1350 psig, initial temperatures to 950 F and back pressures to 300 psig. Along with photographs and cross-sections, the four-page bulletin includes a listing of standard materials, features and accessories, operational types of governors and principal specifications of three sizes for capacities up to 2000 hp.

Separators

The Swartwout Co. has announced a new 12-page bulletin covering the company's line of separators for removing unwanted elements from steam, air and other vapors. Printed in two colors and illustrated with photos, diagrams and line drawings, Bulletin S-14-C gives specifications and selection and ordering data for helico-centrifugal separators.

Synchronous Generators

An eight-page bulletin on Tri-Clad, high-speed synchronous generators has been made available by the General Electric Co. Designated as publication GEA-5415, the bulletin deals with generators for standby, portable and prime-source power for many fields of application. Three typical installation stories add to its value as a catalog dealing with machines rated from 12½ to 1250 kva at speeds from 514 to 1800 rpm.

Chromium Chemicals

A 32-page handbook on chromium chemicals showing their general use and diversified applications in more than seventeen industries has been prepared by Diamond Alkali Co. The brochure presents complete yet concise data on bichromate of soda, its manufacture and principal uses, and a number of methods of analyzing this material. Supplementary to the foregoing are charts and tubes covering equivalent weights, conversion formulas, tank capacities and graphical data.

Flow Meters

A new flow meter bulletin and data book, released by Republic Flow Meters Co., explains and illustrates flow-meter problems and solutions. Meter bodies, differential devices and reading instruments are fully described, and a special section is included on wide range and reverse flow. The 32-page bulletin has an attractive format and is of value as an engineering reference.

Centrifugal Pumps

Type G self-priming pumps manufactured by the La Bour Co., Inc., are described in a 16-page bulletin recently released. One section tells how an effective seal is provided without packing or close clearances, while another provides instructions for the installation, care and operation of Type G pumps.

Business Notes

Hall Laboratories, Inc., Pittsburgh, has named Charles E. Kaufman director of research, succeeding Dr. E. P. Partridge who recently became director of the Laboratories; and John N. Welsh, formerly director of engineering service, has been made associate director of the Laboratories. Also, within the Hagan Corporation group, Dr. Thomas H. Daugherty has been made director of research for **Calgon Inc.**

R. H. Olson, formerly vice president in charge of sales of **Electric Machinery Mfg. Co.,** has been elected president of that company, succeeding W. H. Feldmann, who joined **Worthington Pump and Machinery Corp.** as vice president in charge of sales. Electric Machinery is a subsidiary of Worthington.

Hamilton Merrill, vice president and director of **Manning, Maxwell & Moore, Inc.,** has been appointed vice president in charge of the Consolidated-Ashcroft-Hancock Division of that company.

General Electric Co. has appointed Clarence H. Linder manager of engineering. He was formerly assistant to the general manager of the Company's Apparatus Dept.

Diamond Power Specialty Corp., Lancaster, O., announces the recent election of William P. Fitzburgh, for the past five years assistant to the president and chief engineer, as executive vice president; W. F. Cantieri as chief engineer; and Lyle B. Schueler as sales manager. For the past ten years Mr. Schueler has been associated with the American Gas & Electric Service Corp. as assistant chief mechanical engineer.

Cochrane Corp., Philadelphia, has appointed Ervin J. Bookout eastern sales manager. He was formerly sales engineer in the Philadelphia territory.

Dowell Inc., Tulsa, Okla., announces four major promotions in its field staff. They are W. N. Estel from district manager in Midland, Tex., to sales development manager at Tulsa; R. I. Smith from district manager in Houston to head up activities in western Texas with headquarters at Midland; J. S. Talbot from district sales engineer in Houston to manager of that district; and E. F. Kelly to district engineer in Houston.

Jerguson Gage & Valve Co., Somerville, Mass., has formed an English company, with headquarters in London, in collaboration with the Tress Engineering Co. to merchandise and service its valves abroad. The name of the English company will be **Jerguson Tress Gage & Valve Co. Ltd.**

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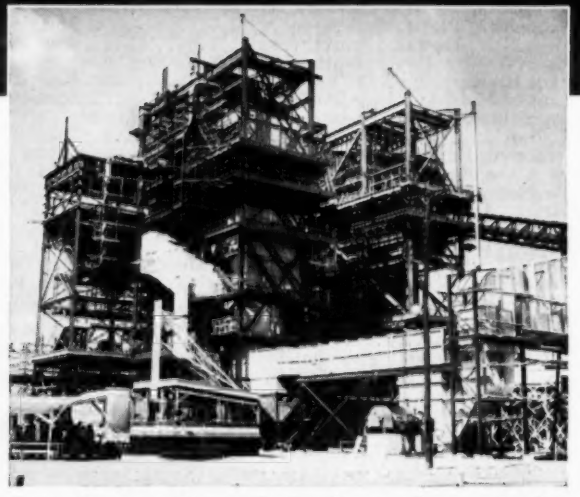

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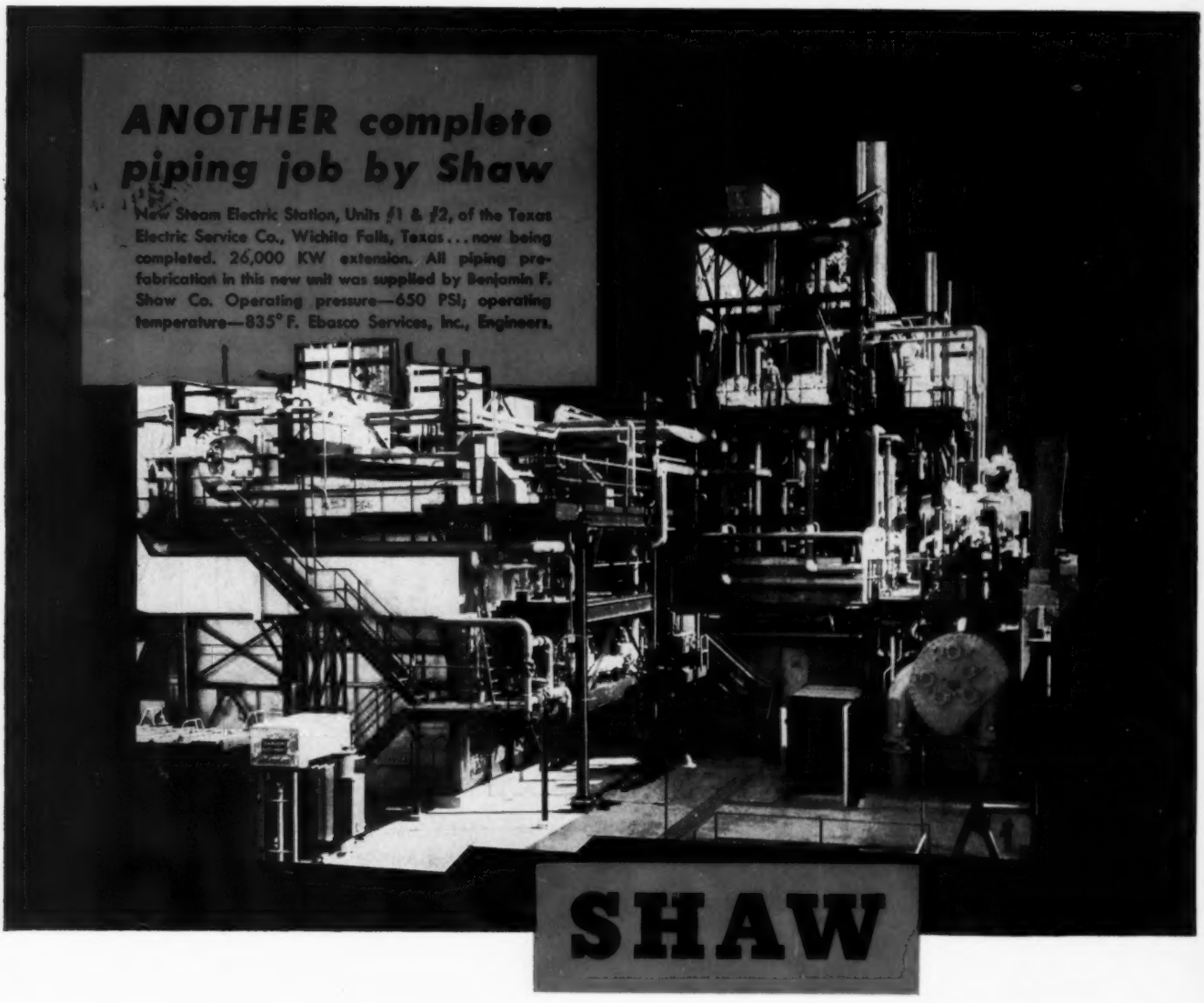
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